JOURNAL
OF THE
AMERICAN SOCIETY OF NAVAL ENGINEERS.

VOL. XVI. AUGUST, 1904. No. 3.

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Rear Admiral JOHN D. FORD, U. S. N., Retired. Lieut. Com. FRANKLIN J. SCHELL, U. S. N.
Commander ALFRED B. CANAGA, U. S. N. Lieut. Com. EMIL THEISS, U. S. N.
Lieutenant MILTON E. REED, U. S. N.

A COMPREHENSIVE EXTRACT FROM THE REPORT OF THE "HOHENSTEIN BOILER" AND "LIQUID FUEL" BOARDS.*

The following extracts have been made, from the voluminous data submitted by these Boards, with a view to placing before the readers of the JOURNAL such portions of the report as will be found of widest general interest for present and future reference.

PRELIMINARY STATEMENT.

CONCLUSIONS DERIVED FROM A COMPARATIVE STUDY OF THE COAL AND OIL TESTS AS DETERMINED AFTER AN EXTENDED SERIES OF TESTS BY THE LIQUID-FUEL BOARD OF THE NAVY.

In view of the cost incurred and labor involved in conducting these experiments, the manufacturing as well as the maritime world will be most interested in noting the practical conclusions reached. The engineering profession will probably find greatest interest in, and attach highest value to, the data collected.

As a result of the extended series of tests the following conclusions have been drawn:

*Commander J. R. Edwards, U. S. Navy; Lieut. Com. W. M. Parks, U. S. Navy; Lieut. Com. F. H. Bailey, U. S. Navy.

1. That no difficulty should be experienced by an intelligent fire-room force in burning oil in a uniform manner. It need likewise require but little experience upon the part of skilled water tenders to be able to detect, either by the character of the roar or hissing noise, or by the color of the flame at different points, an approximate idea both as to evaporative output and efficiency conditions.

2. For general purposes on shore high-pressure steam is a better spraying medium than air. The use of steam, however, as an atomizing agent for naval purposes will undoubtedly require a considerable increase in the size of the evaporating plant, and this must be considered of importance. The necessary increase of the evaporating plant is practically the main objection to the employment of steam as the spraying medium for liquid fuel on board naval and merchant vessels.

3. While the use of steam as a spraying medium will undoubtedly prove most satisfactory for general purposes, the results of the tests show that the consumption of fuel oil cannot be forced to as great an extent with steam as the atomizing agent as when highly heated compressed air is used for this purpose. As the warship is designed to be operated at short notice under the severest forced-draft conditions, the question will have to be considered whether it is not more advisable to fit air burners that would be found most efficient for the day of battle rather than effect an installation of steam burners that are most desirable for general cruising. The advantages of air as the best spraying medium for severe forced-draft conditions is due to the fact that this atomizing agent, after entering the furnace, is a supporter of combustion. With the use of steam as the atomizing agent, the rarified vapor simply displaces a certain portion of air that is requisite for complete combustion. If it were not for the fact that air compressors necessary for supplying an atomizing agent are very bulky and heavy, and require considerable room for their installation, the question might be considered whether for warship purposes it would not be advantageous to effect an installation whereby either the air or steam could be used at will.

4. That in every oil-fuel installation special provision should be made for the removal of the water that will collect from various sources at the bottom of the supply tanks. Even a small amount of water pumped to the burners will interfere with the efficient and satisfactory work of an oil-fuel installation. As it is essential with every boiler installation to secure a uniform if not large output, the annoyance and evil of occasionally pumping water rather than oil to the burners cannot be over-estimated.

5. That the evaporative efficiency of crude and refined oil is practically the same, no matter from what locality the oil may come. The danger of using crude oil, however, is much greater. As it should not be an expensive matter to build refineries near one of the terminal points of a pipe line, the expense of such refining should not increase, to a perceptible degree, the cost of such fuel, since the sale of the by-products of crude oil would often pay, in great part, the expense of distillation.

6. The exceeding benefit of heating the air necessary for effecting combustion cannot be doubted.

7. In order to provide a uniform supply of oil to the burners, the oil should be heated by some simple means. It can be expected that the burners will be operated much more satisfactorily when oil is thus heated.

8. Where the use of a liquid-fuel installation is projected, there should be a reserve of burners installed, and these burners should be of a design that would permit rapid examination, thorough overhauling and easy renewal of special parts by the fire-room force. Careful experiments as well as extended experience have shown that by increasing the number of burners there is not only a more uniform but a more efficient distribution of flame. There is also a minimizing of the blow-pipe effect, as well as a marked reduction in the amount of noise in the furnace.

9. That the hygrometric state of the atmosphere has a noticeable influence upon the efficiency and capacity output of boilers.

10. In order to secure in oil-fuel installation more uniformity of conditions in the furnace and to decrease the noise where air is used as a spraying medium, an air-cushion tank for the oil-sup-

ply pump should be installed. Such a tank would break the pulsation of the pump and serve a similar purpose to that of a regular air chamber of an ordinary feed pump.

11. In view of the liability of every form of burner to clog, the necessity of making special provision for straining the oil was emphatically shown. It would be extremely advisable to install a strainer both on the suction and discharge pipes of the oil-feed supply. These strainers should be of a design that would permit rapid examination and renewal, and one patterned after the Macomb type would meet all general requirements.

12. Extended experience in the burning of crude oil will confirm the opinion that the simpler the furnace, the greater its efficiency. The erection of brick arches only tends, in many cases, to reduce the volume of space necessary for effecting complete combustion. In Scotch boilers there should be a simple vertical brick lining of the back combustion chamber wall, and a lining of the front end of the furnace for about a third of its length.

13. That no design of oil-fuel installation should be permitted for marine purposes which would not permit the renewal within twenty-four hours of all grate and bearing bars, so that a return to coal could be accomplished within a reasonable time in case of failure of oil supply.

14. Where oil is used as a fuel in a Scotch boiler the introduction of retarders in the tubes will undoubtedly increase the evaporative efficiency of the boilers. The use of retarders will prove beneficial by reason of the fact that such devices not only prevent the heated products of combustion from passing too freely through the tubes, but likewise cause a more uniform distribution of these gases in their passage through the tubes to the base of the stack. In thus causing a more uniform and effective heating of the tubes the liability of the end of the tubes to be burned is undoubtedly diminished. With oil as a fuel but little soot forms on the heating surfaces of the tubes. Where retarders are not used in large tubes in an oil-fuel installation it is reasonable to presume that a certain portion of the gases of combustion reach the smokestack without coming into contact with any of the boiler surfaces. Where coal, how-

ever, is used as a fuel in a Scotch boiler, the resulting coating of the tubes by the soot generally reduces their sectional area to a degree sufficient to materially impede the flow of the gases of combustion, and, therefore, under such conditions the gases reach the base of the stack at a comparatively low temperature. Where oil is properly burned it can be regarded as a fact that the velocity of the flow of the gases is greater than where coal is used, and therefore retarders should be used in the case of fire-tube boilers and increased baffling in the case of water-tube boilers.

15. An important point established has been that the calorimeter openings of water-tube boilers should be less than in the case of the Scotch boiler, whether oil or coal be used as a fuel.

16. That marine firemen are not ill-disposed toward the use of oil. It will be essential, however, particularly for marine work, to secure intelligent men for the operation of the burners. It will be found that resulting financial economy will ensue by entrusting the management of oil-fuel installations to men of skill and judgment. Cheap labor cannot be employed in this work; there will be resulting damage, annoyance and danger if the operation of oil-fuel burners is assigned to unskilled labor.

17. That the efficiency of oil plants will be primarily dependent upon the character of the installation of fittings and auxiliaries. The form of the burner, so long as it is manufactured in accordance with general well-known principles, and all its parts are accessible for overhauling, will play a very small part in extending the use of crude petroleum. The method and character of the installation, is all-important, and therefore the work of designing and constructing such a plant should only be entrusted to those who have given careful study to the matter and who have had extended practical experience in burning the crude product. Consumers should take special care that they neither purchase appliances that have been untried, nor permit the installation to be effected by persons who have had but limited experience in such work.

18. Where crude petroleum has undergone a slight refining or distillation no ill effects result to modern steel boilers. From

the standpoint of endurance of the boiler, the advantage, if any, is with oil. Crude oil, however, by reason of its searching and corrosive effects, has a greater tendency than refined oil to attack the seams and tubes of modern boilers. For marine work, therefore, no crude petroleum should be used, and particularly for ships making long voyages the fuel oil should undergo some mild distillation before being placed in the tanks.

19. That in the stowing of liquid fuel on board vessels, whether taken on board for fuel purposes or for transportation in bulk, the compartments containing the crude product should be as few as possible, both for reasons of safety as well as for facility of delivery and discharge.

20. That with the use of oil the forcing of a marine boiler should be accomplished much more readily than with the use of coal.

21. That under forced-draft conditions, and with water-tube boilers, and with the use of oil as fuel, the solution of the smoke question is nearly as remote as ever. Where a limited quantity of oil is burnt in a Scotch boiler, however, and retarders are used in the tubes, crude petroleum should be smokeless.

22. The value and necessity of installing a series of draft gauges between the ash pan and the base of the stack was conclusively shown. As a result of the study of the draft conditions at different points there were changes made in baffling the gases which were of decided benefit. It is, therefore, recommended that a series of draft gauges be fitted to the boilers of several large ships burning coal for experimental purposes, since the Board is of the opinion that marked gain both as to the efficiency and capacity of naval boilers would be secured by a careful observation and study of the draft condition at various points between ash pan and smokestack.

23. In order to secure for the day of battle increased speed for warships, naval administrators are justified in demanding of manufacturers of water-tube boilers increased coal consumption per square foot of grate surface. The weight thus saved in the reduction of the number of boilers should be exclusively applied to giving the machinery greater endurance by using heavier

boiler linings and casings, and more substantial auxiliaries. The space gained in the reduction in the number of boilers should be assigned to providing increased sized fire rooms, evaporator rooms and passage way in the boiler compartments. The fire-room conditions on board the modern battleship could not be much worse, whether viewed from the standpoint of providing for sanitary stokeholes or for an arrangement of fire rooms, where not only efficient stoking can be carried on, but an installation in which there are adequate facilities for rapidly effecting routine examination and repairs. It is not surprising that there is excessive expenditure as regards cost of repairs, rapid and excessive depreciation, and that the boiler endurance is exceedingly limited when marine steam generators are crowded in the manner in which they are now installed. Under existing fire-room conditions auxiliary feed and bilge pumps are likewise installed directly in the fire room and even in niches cut out of the bunker compartments. As now arranged the character of the installation of these appliances not only interferes with efficient stoking and repairs to the boilers, but the pumps themselves are constantly under either repairs or examination, due to the dust and grit which settles upon their working parts, and thus causes their early renewal. There can be no satisfactory installation of either coal or oil-burning appliances until an increase of space is allowed for the operation and preservation of the boiler plant.

24. The absolute lack of endurance of both Scotch and mica water-gauge glasses for installation in boilers carrying over 250 pounds pressure, and subject to forced draft usage, was conclusively established. Reflex water-gauge glasses should alone be used on boilers which are subject to heavy forced-draft conditions.

25. Practically every form of commercial fire brick that was used in the boiler for the purpose of forming a deflecting arch disintegrated under the action of the intense heat generated. In case any form of arch or bridge wall is essential to the efficient or forced burning of liquid fuel, then special experiments should be conducted to secure a refractory brick that would possess endurance under the severest of forced-draft conditions.

26. For naval installations there should be supplied a fuel oil that will not flash under 175 degrees Fahrenheit. The higher flash point required for naval than for merchant vessels is essential for the following reasons:

(a) The war vessel must be kept in readiness to proceed to the tropics at immediate notice, and the firing of the guns subjects the naval ship to danger conditions to which other types of vessels are not exposed.

(b) The fitting of numerous transverse bulkheads and a protective deck in a naval installation, combined with the fact that both machinery and boilers are exceedingly crowded, makes it extremely difficult to properly ventilate certain compartments, and therefore in warships it will be necessary to use special precautions both in the stowing and in the handling of oil fuel.

(c) The fact that a large number of men must be permanently housed beneath decks on the naval ships will make it difficult to prevent the use of open lights in some of the lower compartments, and thus, from this cause, the danger of using oil as a fuel will always be greatest in naval vessels.

27. There should be no attempt made to use oil as auxiliary or supplementary to coal. Such an installation is certain to prove unsatisfactory, and the solution of the oil-fuel problem for naval purposes is only delayed by any attempt to inject a limited supply of oil fuel over a bed of incandescent coal. The mechanical features of the problem having been satisfactorily met, the good of the service requires that any installation attempted should depend alone upon oil as a fuel and not any combination with coal.

28. In maritime construction no oil fuel should be carried in compartments directly beneath the boilers. In case such compartments should ever be used as oil reservoirs there might be danger of radiated heat from the boilers volatilizing and exploding some of the hydro-carbons of the fuel oil. In case also there was any puncturing of the inner bottom the hot ashes might reach the oil. The possibility that the oil may reach the bilges through improper manipulation of the valves of the manifold boxes is exceedingly liable to be realized.

29. The importance and necessity of always possessing a reserved supply of superior fuel was strikingly impressed upon the Board, for both during the coal and oil experiments there was resulting delay due to the non-delivery of fuel. Special effort was made at all times to maintain a reserve supply of coal, but from causes beyond the control of the Board, shipments of such fuel would be delayed. Particularly was it found difficult to secure hand-picked coal of superior quality, and in one instance such fuel could only be secured within reasonable time by having it shipped at express rates to the experimental plant. The necessity of maintaining at every naval station a large invoice of hand-picked coal of the very best quality, to be utilized for emergency and experimental purposes, was repeatedly emphasized. As for a reserve of coal for war purposes, it is highly probable that in a contest for the command of the sea an adequate reserve of fuel may be only one remove in importance from the possession of a reserve of ships.

30. In view of the fact that 48 per cent. of the world's output of crude petroleum is produced in the United States, and that practically our entire yield is secured from fields which are in pipe-line communication with important maritime and strategic ports, the Board considers that a joint commission representing commercial, manufacturing, maritime and naval interests should be authorized by Congress, whose province it would be to formulate such rules and regulations as would provide for an economical, efficient, enduring and safe oil-fuel installation. Heretofore the oil-fuel problem has been principally investigated by various individual interests which have sought to secure information along certain lines, and as a result there has not been secured that knowledge of the subject which would insure for the country at large such development of the use of crude oil for fuel as would be warranted, considering the natural advantages possessed by the United States in having at its command near great seaports so large a proportion of the world's production of the crude product. Particularly for the development of our commercial interests in the Gulf of Mexico and on the Pacific coast would the work of such commission have an important influ-

ence in extending our prestige and power, whether viewed from a commercial, maritime or naval standpoint.

31. The Board regards the engineering or mechanical feature of the liquid-fuel problem as having been practically and satisfactorily solved. For manufacturing purposes the financial and supply features are the only hindrances to the use of crude petroleum as a standard fuel. For mercantile purposes the commercial and transportation features of the problem are existing bars which limit the use of oil fuel for merchant ships. For naval purposes there is the additional serious difficulty to be overcome of providing satisfactory and safe structural arrangement for carrying an adequate bunker supply.

32. That in the consideration of the problem of attempting to use oil as a fuel for either marine or naval purposes it should be particularly remembered that, by reason of the economic and commercial demands of crude oil for illuminating, lubricating and other purposes, the available supply of the world's production of crude petroleum that could be used as a fuel would not meet over 3 per cent. of the world's demand for coal and other combustibles. For a time, therefore, the effort should be made to use oil fuel only for special purposes in particular localities.

33. The Board considers that what will eventually be recognized as the most important result of these extended experiments is the collection of a great mass of trustworthy data concerning the comparative value of coal and oil as a fuel under various conditions. It should be observed that these data were taken with exceeding care and checked at the earliest practicable time after each test. Wherever it was found that discrepancies existed in any experiment the test was repeated in order to discover, if possible, the cause of the inconsistency. There have also been secured very complete and trustworthy data in regard to boiler efficiency and capacity.

In conclusion, the Board desires to call attention to the fact that these experiments continued uninterruptedly for a period of twenty-eight months, and that for a considerable period of this time there were no fewer than six commissioned officers giving

special consideration to this subject. There were also employed in connection with this duty skilled draftsmen and experts of the Bureau of Steam Engineering as well as members of the Bureau's clerical staff. For one year there was available for this experimental work the entire crew of the torpedo boat *Rodgers*.

The work represents an immense amount of labor, and as the Board has been in correspondence with nearly every interest directly or indirectly concerned with the use of oil as a combustible, it is believed that the report submitted will not only be of value to the Navy Department, but to the manufacturing and mercantile interests of the nation.

Very respectfully,

JOHN R. EDWARDS,
Commander, U. S. N., Member;
W. M. PARKS,
Lieutenant Commander, U. S. N., Member;
F. H. BAILEY,
Lieutenant Commander, U. S. N., Member.

To the CHIEF OF THE BUREAU OF STEAM ENGINEERING.

DEPARTMENT OF THE NAVY,
BUREAU OF STEAM ENGINEERING,
WASHINGTON, D. C., *Aug. 1, 1904.*

Sir: The undersigned, appointed a Board to conduct an extended series of tests to determine the merits of the Hohenstein water-tube boiler as a steam generator of approved type for ships of war, and for investigating the relative value of coal and oil as a fuel for naval purposes, submits the following report:

The water-tube boiler used during these tests was of the straight large-tube type, and was built to conform to the requirements of weight, capacity and space occupied by one unit of the boiler installation of cruisers of the *Denver* class. Each unit of the boiler installation of vessels of the *Denver* class is required under forced draft of 1-inch water pressure, and under 275 pounds steam pressure, to evaporate 12,000 pounds of water per

hour under actual steaming conditions. On the basis of 16 pounds of water per indicated horsepower per hour there would thus be developed for main engines and circulating pumps about 15 I.H.P. per hour per square foot of grate surface, a requirement that is not exceeded by any other installation of straight large-tube type of boiler in the United States Navy. When using forced draft during both coal and oil tests, this designed capacity was greatly and repeatedly exceeded without detriment to the tubes and drums, and therefore speaks well for the efficiency and endurance of the design and workmanship of the boiler under test.

As comparative data is of the greatest practical value in affording information or determining results, it should be stated that coal was the fuel used from April 23, 1901, to January 11, 1902, when determining the evaporative efficiency, capacity, reliability and endurance of the design of the experimental boiler.

A careful study of the data and summary of the coal and oil tests ought thus to furnish comparative and reliable information, and enable marine-boiler designers, as well as all having a direct interest in the boiler problem, to note for themselves the relative advantages and disadvantages of the two kinds of fuel when tested under as nearly similar conditions as could possibly be secured.

GENERAL DIMENSIONS OF THE HOHENSTEIN BOILER USED FOR CONDUCTING THE COMPARATIVE TESTS.

Drums.—There are six steam drums, forming a double hollow parallelopipedon. There is a front drum, 24 inches in diameter; a rear drum, 24 inches in diameter, and four connecting drums, each 16 inches in diameter. There is also a lower rear mud drum 24 inches in diameter.

Tubes.—There are sixteen 4-inch tubes 7 feet long, three hundred and eighty-four 2-inch tubes 9 feet long, and fifteen 5-inch downtake tubes, which are connected to the rear steam drum and to the mud drum.

Heating and Grate Surface.—There are 2,130 square feet of

heating surface and 50.14 square feet of grate surface. Ratio of heating surface to grate surface, 42.5 to 1.

Floor Space.—Nine feet wide, 10 feet 11¼ inches deep.

Height over all.—Twelve feet 6⅜ inches.

Volumes.—Water at steaming level, 142 cubic feet; steam space, 50 cubic feet; furnace volume above grate bars, 121.14 cubic feet.

Weights.—Boiler and fittings, excluding uptake and smoke pipe:

With water, pounds	54,127
Without water, pounds	46,668

Per square foot of heating surface at steaming level and at 275 pounds pressure:

With water, pounds	25.4
Without water, pounds	21.8
Water per square foot grate surface, pounds	1,080

Ratios.—Area of grate to area of air spaces (average for all the tests with coal), 1 to 0.57.

Measurements of Smokestack.—Height of stack above the grate, 70 feet; cross section of smokestack, 8.73 square feet; ratio of smoke pipe area to grate area, 1 to 5.75.

SPECIAL CHARACTERISTICS OF THE EXPERIMENTAL BOILER.

Drums.—The arrangement of the drums provides for a large body of water within them, thus affording a marked steadiness of water level. The design of these drums likewise secures a large steam-liberating area, as well as a space above the water level sufficient to insure unusual dryness of steam.

Arrangement of Tubes.—A most noteworthy feature of the boiler is the arrangement of the tubes in pairs, in such a way that each tube is free to expand independently of other tubes, thus effectually preventing longitudinal stresses. The tubes, instead of being expanded into rigid headers at both ends, are so arranged that at least one end of each tube is expanded into a junction box.

There are two sizes of tubes. Sixteen of these tubes are 4 inches in diameter, and are the ones which are subjected to the greatest heat and strain. These large tubes are expanded into a mud drum at the rear end, the drum being of sufficient size, however, to permit a man to enter either to make examination or repairs. It requires but the removal of a single plug either to examine or to clean any large tube.

There are 384 2-inch tubes whose ends are expanded into junction boxes. The removal of these tubes was easily effected, a test of the time and difficulty attending this operation having been exacted during the experiments by the Board.

There are fifteen 5-inch downcast tubes. The comparative sectional areas of generating tubes and of downcasts is such that the carrying capacity of the latter is more than ample to supply the generating tubes. There is room between the downcast tubes and the rear set of junction boxes for a man to enter to remove plugs and cut out the tubes, thus permitting for naval construction the downcast tubes to be placed quite close to the athwartship bulkheads.

Junction Boxes.—In each element or cycle of tube arrangement there is but one junction box to impair the flow of circulation. As it will undoubtedly be found that in every form of straight water-tube boiler there will be buckling of the tubes in case some provision is not made for allowing for expansion, the introduction of a single junction box should have important advantages. Such a junction box is free to accommodate itself to any irregularities due to the expansion or contraction of the tubes. It was observed during one of the fuel-oil tests that when the front casing was removed and fires lighted under the cold boiler that the displacement of one of the lower front junction boxes did not exceed one-eighth of an inch in the vertical plane.

Efficiency of the Composition Plugs.—Opposite every tube end composition plugs have been fitted in the junction boxes. These plugs are of two sizes, $2\frac{3}{8}$ inches and $4\frac{1}{2}$ inches in diameter, with, respectively, $11\frac{1}{2}$ and 8 threads per inch. The threads are lubricated with graphite. Some of the plugs are made with tapering threads, and depend for tightness on these threads alone. It was

thought that the relative high coefficient of expansion of the composition plug would cause the plug to be tight under steam, and easily removable when cold. It was found necessary, however, to cut out some of these plugs when it was desired to examine the tube, thus showing that the composition when expanded had taken a permanent set, somewhat resembling cast iron in this respect.

The plugs with parallel threads were packed, under the narrow flange at the end, with Merwath gaskets. These gaskets consist of concentric copper and lead rings soldered together. The plugs secured in this way were easily removed and found to be tight under pressure.

Character of the Circulation.—Attention is called to the fact that the entire down flow of circulation takes place within the 5-inch vertical tubes, which are located in a comparatively cool place, while, on the other hand, there is invariably an upward trend to the circulation in all horizontal tubes and headers exposed to the hot gases. It is highly improbable that there are reverse currents at any part of the water circuit. The feed water is introduced at the top of the down-take tubes, which is obviously the best possible place as regards influence on the circulation. At the same time the head due the velocity of the feed water is augmented by means of injector nozzles pointing in the direction of the flow.

GENERAL ARRANGEMENT OF THE AUXILIARIES OF THE EXPERIMENTAL PLANT.

Airtight Steel Structure.—The boiler was erected in a steel structure built especially for these tests. The following are the general dimensions of this airtight building: Floor space, 16 feet by 24, and height, 14 feet. There was an air lock for entrance and exit during forced-draft trials. There were seven windows fitted that could be opened during natural-draft trials.

Compressors.—There was a Root blower (No. 3 size) driven by a direct-connected engine 8 by 9 inches which was capable of delivering 8 cubic feet of free air per revolution, at pressures

ranging from ¾ pounds to 5 pounds per square inch. There was also a Rand air compressor of the very latest design capable of giving pressures up to a hundred pounds per square inch. The following are some of the dimensions of this blower:

	Inches.
Steam cylinder:	
Diameter	10
Stroke	14
Compressor:	
H. P.	10
L. P.	16

Pumps.—There was installed a Davidson suction pump, a Snow high-pressure feed pump and several Blake pumps. It was exceedingly unfortunate that a larger size feed pump was not installed, since the evaporative capacity of the boiler under test exceeded the limit of the feed supply that could be furnished by the Snow pump.

Blowing Engine.—There was a direct-connected blowing engine and fan. The fan had an impeller 72 inches in diameter and a discharge duct 20 inches by 42 inches, which led to the fireroom and terminated in a box placed so as to direct the air current toward the ceiling.

Measuring Instruments.—Standard scales, test gauges and other instruments of precision were used so that the most accurate data possible could be collected.

MANNER IN WHICH THE WEIGHT OF COAL, WATER AND REFUSE WAS ASCERTAINED.

Feed Water.—The feed water was generally muddy. The supply was drawn from the Potomac river through a suction pipe that ran out to the end of a dock. No test was either delayed or stopped solely on account of the character of the feed, and there were times when an unusually heavy quantity of mud was in this feed supply.

The feed water was weighed in two circular tanks holding respectively 1,046 and 1,047 pounds of water each, and resting on 1,500-pound Howe scales. These scales had been tested by

the city's sealer of weights and measures. The scales and weighing tanks were on a platform above the feed tank. The weight of each tank when filled was recorded, and then the water was allowed to flow into the feed tank as needed. As soon as the weighing tank was emptied the weight was again taken and the time noted. The feed tank was provided with a graduated water-level gauge. The height of water by this gauge was noted at the moment of beginning the test, and at the end of each hour it was again brought to the same level. The feed tank had a steam coil for heating the water. Wide variations in the temperature were easily avoided by keeping the water level in the tank fairly constant.

In some of the forced-draft trials the weighing tanks had to be filled, weighed and emptied with such rapidity, owing to their insufficient size, that the above method of catching the weight at the end of each hour could not be used. The weighing tanks were accordingly each fitted with a water-level gauge graduated to 5 pounds, by the aid of which the weight within 5 pounds could be caught at any moment without interfering with the rapid manipulation of the tanks. The temperature of the feed water was taken at an elbow of the feed pipe between the pump and the boiler.

ACTUAL WEIGHT OF WATER CONTAINED IN BOILER.

The following determination was made of the actual weight of water contained in the boiler at a temperature of 56 degrees Fahrenheit and at different gauge-glass readings, the correct steaming level being at 1 inch:

Height of water in gauge.	Total weight of water.	Difference.	Area of water level.
	pounds.	*pounds.*	*sq. feet.*
0	8,588		
1 inch	8,869	281	52.2
2 inches	9,235	366	70.5
3 inches	9,648	413	79.6
4 inches	10,033	385	74.2
5 inches	10,405	372	71.7

Coal.—The coal was weighed in sheet-metal cans or bags, the method being to adjust each can or bag to a uniform weight of 220 pounds or 130 pounds while on the scales, and then keep tally of the number passed into the fire room. Beginning with the seventh test, the coal account was balanced at the end of each hour by estimating and deducting the weight of coal lying at the moment on the fireroom floor.

Refuse.—The ashes and refuse were weighed in sheet-metal cans as they accumulated, and the weight of sweepings from tubes and baffles was carefully ascertained. By reason of the coal tests being limited to periods of short duration, there was practically no cleaning of fires, and thus the percentage of refuse is much smaller than would occur under actual sea-going conditions.

CHARACTER OF THE STEAM EVAPORATED.

The quality of the steam was determined by means of a Barrus throttling calorimeter, which drew steam from the main steam pipe at a point 8 inches in front of the boiler. The sampling nozzle consisted of a half-inch pipe reaching nearly across the steam pipe in a horizontal diameter. This pipe had four rows of perforations extending the length of the diameter of the inside of the steam pipe—say, for 1½ inches at each end. An extra calorimeter was fitted and readings were taken from both calorimeters throughout the series of trials, except when, as once occurred, the extra calorimeter got out of order by the lodgment of black scale in its throttling orifice.

CHARACTER OF THE COAL USED.

From each can or bag of coal that was brought into the fireroom, a specimen was taken and collected in a box, so that there could be forwarded for analysis a fair sample of the fuel used.

The following table gives the result of analyses of samples of each lot of coal. The analyses were made by the chemist at the New York Navy Yard:

	Pocahontas coal, run of mine.		New River coal, run of mine.	Pocahontas coal, hand picked and screened.
	Fuel burned in boiler test No.—			
	1, 2, 3.	4, 5, 6.	7, 8, 9.	10 to 17.
Proximate Analysis.	*per cent.*	*per cent.*	*per cent.*	*per cent.*
Fixed carbon	73.30	75.78	72.99	76.81
Volatile matter	17.61	19.53	21.79	19.62
Moisture	.49	.79	.49	.73
Ash	8.60	3.90	4.73	2.84
	100.00	100.00	100.00	100.00
Sulphur, separately determined	.48	.71	.46	.82
Ultimate Analysis.				
Carbon	82.26	84.96	83.60	85.94
Hydrogen	3.89	4.07	4.85	4.45
Oxygen	4.12	5.46	4.87	4.50
Nitrogen	.64	.90	1.41	1.14
Sulphur	.49	.71	.46	.82
Ash	8.60	3.90	4.81	3.15
	100.00	100.00	100.00	100.00
Calorific Value (B.T.U.'s per pound).				
Coal	14,067	14,534	14,841	14,992
Combustible	15,391	15,124	15,684	15,475

THE COMPOSITION AND TEMPERATURE OF FLUE GASES.

Samples of the flue gas were drawn from the smokestack by means of an aspirator improvised from two half-gallon bottles. The sampling tube was one-half inch diameter and extended to the center of the stack, the inner end being nearly closed and the sides being perforated with one-eighth inch holes, spaced 4 inches apart. The aspirator, charged with gas, was carried to a neighboring building, where the sample was analyzed by the aid of an Orsat apparatus.

The temperatures at the base of the stack and the samples of flue gas were taken above the roof at a point about 5 feet from the nearest heating surface of the boiler, measured along the path of flow of the gases. In the natural-draft trials the temperatures were taken with a mercury-nitrogen pyrometer, and attempts were made to do the same in the forced-draft trials. Momentary flaming in the stack, however, caused so many breakages of glass

bulbs that reliance had finally to be placed on a Brown quick-reading pyrometer, the readings of which were, however, checked as well as could be by the melting points of zinc, aluminum and copper.

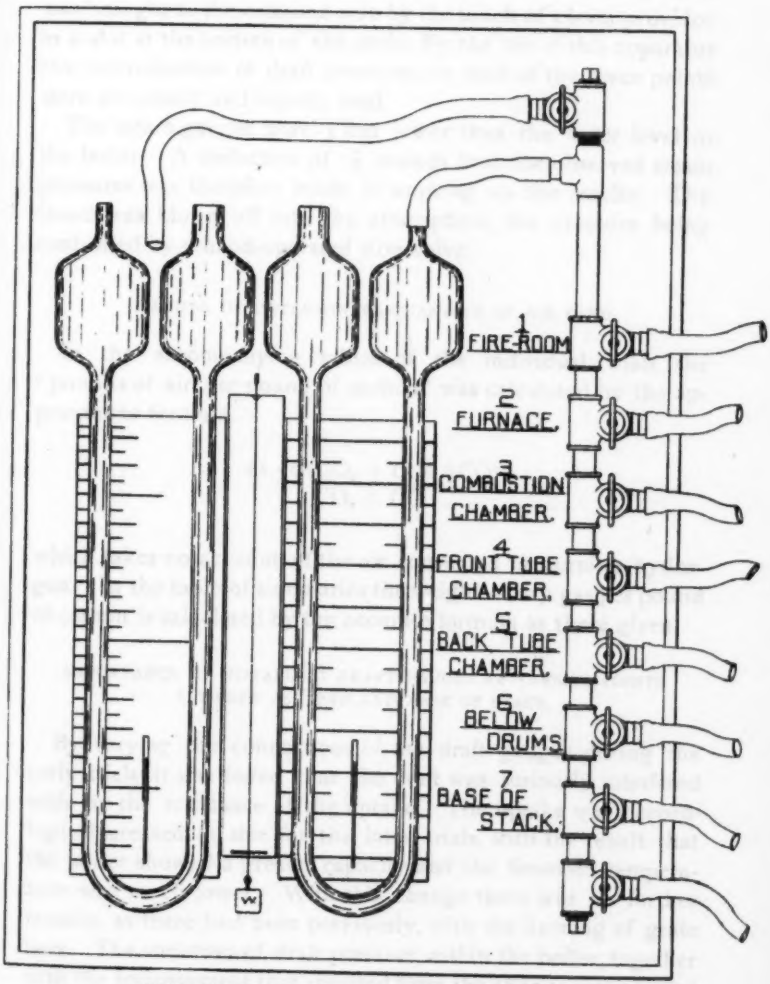
Exceptional care was taken in the collection of all data relating to the flue gases, in order that some definite information might be secured as to the temperature of gases at various points as well as to determine the best means of installing baffling. The increased efficiency of the water-tube boiler will undoubtedly be secured by changes in baffling, whereby the flow of gases will be more greatly impeded and the removal of soot more quickly effected.

ARRANGEMENT OF PRESSURE GAUGES.

The several air pressure and steam gauges were placed near each other on the wall of the steel structure, and particular care was taken in the fitting of necessary pipe connections.

The following sketch (1*b*) shows the arrangement designed by the Board to quickly read the air pressure at any point of the boiler between the ash pit and the base of the stack. In the bent tube at the left, liquids of different densities were introduced so that light variations in pressures could be quickly detected. As compared with the bent tube at the right, the tube at the left showed variations in the pressure magnified ten times.

The apparatus consists of a pair of U-shaped glass tubes, with expansions formed at the top of each tube, for the purpose of augmenting the surface of the liquid in the tubes exposed to the action of the gas pressures. The successive introduction of the pressure to the top of the liquid in one tube was provided for by the use of a rubber-tube connection to the top of what might be regarded as a gas switchboard or gas manifold. By turning the proper gas cock the pressure could be brought from any of the points on the boiler, as indicated by the lettered name plate, and its effect brought to bear on the surface of the liquid in one of the bulbs. The U tubes were filled with non-mixing liquids of different densities and different colors, so arranged that the line of demarcation between the two liquids would come approximately to the middle of the length of each limit of the U. Before



DRAFT GAGE INSTALLATION FOR BOILER TESTS.

Fig. 1b.

beginning a reading the graduated scale at the back of the tubes was brought to the common zero by the touch of a lever provided in a slot at the bottom of the scale. By the use of this apparatus the determination of draft pressures for each of the seven points were accurately and rapidly read.

The steam gauges were 3 feet lower than the water level in the boiler. A deduction of 1½ pounds from the observed steam pressures was therefore made in working up the results. The steam was blown off into the atmosphere, the pressure being controlled by a hand-operated stop valve.

MANNER OF DETERMINING QUANTITY OF AIR USED.

In the accompanying tables of the individual trials the "pounds of air per pound of carbon" was calculated by the approximate formula,

$$\frac{11.55\ (CO_2 + O + \frac{1}{2}CO)}{CO_2 + CO}$$

which takes no account of the air consumed in burning hydrogen. In the table of summaries the weight of dry gas per pound of carbon is calculated by the accurate formula as there given.

IMPORTANCE OF INSTALLING DRAFT GAUGES AT VARIOUS POINTS BETWEEN ASH PAN AND BASE OF STACK.

varying the connections of the draft gauges during the ea / trials it was found that the draft was seriously interfered with by the resistance of the uptake. The uptake was accordin ly increased in size for the later trials, with the result that the boiler showed a greater capacity and the fireroom temperature was much lower. With this change there was no further trouble, as there had been previously, with the burning of grate bars. The variation of draft pressure within the boiler, together with the improvement that resulted from the change just alluded to, is shown diagrammatically in Fig. 3.

SUMMARY OF SEVENTEEN TESTS OF HOHENSTEIN

Number of trial.	Date of trial.	Duration of trial (hours).	Kind of fuel (P., Pocahontas coal; N. R., New River coal, r. m., run of mine; h. p. s., hand picked and screened).	State of weather.	Height of barometer at noon.
1	2	3	4	5	6
	1901.				
1	Apr. 23.	8	P., r. m.	Clear	30.02
2	Apr. 26.	6	do.	Dull and overcast	30 12
3	May 8.	4	do.	do	29.86
4	May 29	8	do.	Squally	29.70
5	June 5.	6	do.	Bright and sunshiny	30.08
6	June 8.	3½	do.	do	29.95
7	Oct. 21.	8	N. R., r. m.	Clear	30.34
8	Oct. 23.	6	do.	Cloudy	29 95
9	Oct. 26	4	do.	Smoky	30.25
10	Nov. 6.	8	P., h. p. s.	Clear and damp	30 20
11	Nov. 9.	8	do.	Cloudy, occasional sun	30.18
12	Nov. 18.	6	do.	Gray and overcast	30 09
13	Nov. 27.	4	do.	Thin clouds	30.23
14	Dec. 16.	6	do	Smoky, with thin clouds	30 13
15	Dec. 18.	8	do.	do	30.01
16	Dec. 21.	4	do.	Smoky, no clouds	30.28
	1902.				
17	Jan. 11.	3	do.	Dark, fog, and smoke	29.58

Number of trial.	Approximate fire-room air pressure.	Average temperature.					Fuel.					
		External air (°F.).	Air in fireroom (°F.).	Chimney gases (°F.).	Feed water entering boiler (°F.).	Steam at gauge pressure (7) from steam tables (°F.).	Weight of wood used in starting fires (pounds).	Weight of coal used in starting fires (pounds).	Weight of coal used during test (pounds).	Total weight of fuel used (pounds), (21) + (22) + (23).	Weight of ashes before beginning test (pounds).	Weight of ashes during test (pounds).
1	8	16	17	18	19	20	21	22	23	24	25	26
1	0	57.2	93.8	594	144	410.4	350	2,400	9,720	12,470	260	377
2	1	70.3	117.8	751	145.4	413.3	300	2,000	10,445	12,745	160	575
3	2	72.8	121.7	1,089	145.8	413.7	390	2,500	10,569	13,459	195	459
4	0	64.4	114	688	137	412.7	340	2,000	8,633	10,973	175	226
5	1	84.1	139.5	712	129 3	413.1	300	2,200	10,695	13,255	200	1,038
6	2	74.8	127.3	1,1c 5	116.5	412.5	?	?	8,461	8,461	?	591
7	0	71.3	144	563	131.8	413 6	360	2,000	8,056	10,416	198	485
8	1	74 3	124	654	126.1	413 6	250	1,910	9,698	11,858	161	365
9	2	68	106.5	688	111 8	413.6	361	2,200	9,000	11,561	152	391
10	0	62.7	125	548	125.9	413.6	350	2,792	8,299	11,441	225	214
11	0	55 1	125.4	521	122.3	413.6	350	1,435	7,436	9,221	303	584
12	1	52	105	580	119.7	413.6	350	2,762	8,388	11,500	526	837
13	2	40.2	86	717	92.4	413.6	310	2,762	10,694	13,766	267	460
14	1	32.3	77	766	104.6	413 6	330	3,256	14,029	17,635	271	714
15	0	26	87	568	125	413 6	360	2,440	9,181	11,981	235	702
16	2	22	64	800	98.4	413.6	450	3,130	12,612	16,192	105	646
17	3	35.4	76.5	943	88	413 6	350	3,554	10,862	14,766	151	254

[This boiler is shown opposite page 213, JOURNAL, Vol. XV, No. 1, February, 1903.]

MARINE WATER-TUBE BOILER BURNING COAL.

Average pressures.								
Steam pressure by gauge; corrected for water level, pounds per square inch.	Draft pressures, in inches of water.							Revolutions of blower per minute.
	Fire-room.	Ash pit.	Furnace.	Combustion chamber.	Tube chamber.	Above tubes and below drums.	Base of stack.	
7	8	9	10	11	12	13	14	15
263.9	0 0	—0.05	.....	.....	.....	.....	—0.52	0
272.9	1.08	1 02	.....	.....	.....	.....	— .65	250
274.6	2.06	2	.....	.....	.....	.....	— .84	335
271.3	0.0	— .04	—0 18	—0.20	—0.21	.....	— .24	0
272.5	1.06	1.02	.80	.62	.....	.....	— .41	243
270.5	2.03	2	1.56	1.41	.....	.....	— .22	375
273.5	0.0	— .05	— .16	— .12	— .22	.....	— .50	0
273.5	1.07	1	.81	.72	.52	.....	— .46	243
273.5	2.10	2	1.43	1.25	1.08	.....	— .98	375
273.5	0.0	— 05	— .15	— .14	— .19	.....	— .55	0
273.5	0.0	— 05	— .09	— .09	— .11	.....	— .55	0
273.5	.99	.97	.79	.69	.51	.....	— .55	240
273.5	2.10	2.00	1 58	1.18	.86	.....	— .77	375
273.5	...	1.00	.57	.32	.06	—0.20	— .59	243
273.5	...	0	— .20	— .20	— .25	— .38	— .51	0
273 5	..	2.00	1 41	.93	.24	— .07	— .64	332
273.5	...	3.00	2.16	1.44	.82	.10	— .55	423

Fuel.								Steam.	
Weight of refuse from furnace, tubes, baffles, etc. (pounds).	Total weight of ashes and refuse (pounds), (25) + (26) + (27).	Percentage of ashes and refuse, (28)÷(24)×100.	Weight of ashes and refuse from coal used during test (pounds), (23)×(29) ÷ 100.	Percentage of moisture in coal (* by weighing and drying sample; † by chemical analysis).	Weight of moisture in coal used during test (pounds) (23) × (31) ÷ 100.	Weight of dry coal burned during test (pounds), (23) — (32).	Weight of combustible burned during test (pounds), (33) — (30).	Quality of steam.	Percentage of moisture in steam, 100—100×(35).
27	28	29	30	31	32	33	34	35	36
640	1,277	10.24	995	*0.50	49	9,761	8,676	0.980	2
550	1,285	10.08	1,053	* .50	52	10,393	9,340	.968	3.2
815	1,469	10.91	1,153	* .50	53	10,516	9,363	989	1.1
549	950	8.66	747	† .79	68	8,565	7,818	.990	1
539	1,777	13 40	1,432	† .79	85	10,610	9,178	.988	1.2
626	1,217	14.37	1,216	† .79	67	8,394	7,178	.990	1
561	1,244	11.95	963	*3.14	253	7,803	840	.986	1.4
528	1,054	8.89	862	*3.14	304	9,394	8,532	.976	2.4
732	1,275	11.03	993	*3.14	283	8,717	7,724	.980	2
526	965	8.44	700	*2.04	169	8,130	7,430	.988	1.2
316	1,243	13.48	1,003	*1.15	85	7,351	6,348	.987	1.3
562	1,925	16 75	1,405	*1.59	134	8,254	6,849	.983	1.7
936	1,663	12.08	1,292	*1	107	10,587	9,295	.979	2.1
923	1,908	10.82	1,518	† .73	102	13,927	12,409	.980	2
576	1,513	12.63	1,160	† .73	67	9,114	7,954	.985	1.5
895	1,646	10.18	1,285	† .73	92	12,520	11,235	.978	2.2
1,355	1,760	11.92	1,295	† .73	79	10,783	9,488	.974	2.6

SUMMARY OF SEVENTEEN TESTS OF HOHENSTEIN

Number of trial.	Approximate fireroom air pressure.	Water. Total weight of water fed to boiler (pounds), corrected for inequality of water level and steam pressure at beginning and end of test).	Water. Equivalent weight of water evaporated into dry steam (pounds), (37) × (35).	Water. Factor of evaporation $H-h+965\ 7$.	Water. Equivalent weight of water evaporated into dry steam from and at 212 °F. (pounds), (38) × (39).	Economic results. Feed water per pound of coal as fired (pounds) (37) ÷ (23).	Economic results. Equivalent evaporation from and at 212 °F. per pound of coal as fired (pounds), (40) ÷ (23).	Economic results. Equivalent evaporation from and at 212 °F. per pound of dry coal (pounds), (40) ÷ (33).	Economic results. Equivalent evaporation from and at 212 °F. per pound of combustible (pounds), (40) ÷ (34).
1	8	37	38	39	40	41	42	43	44
1	0	76,016	74,455	1.134	84,430	7.82	8 69	8.73	9.74
2	1	86,673	81,260	1 133	92,060	8.30	8.81	8.86	9.86
3	2	79,803	78,700	1.133	89,170	7.55	8.44	8 48	9 52
4	0	77,953	77,120	1 142	88,070	9.03	10 20	10.28	11.26
5	1	92,458	91,300	1 150	104,740	8.65	9 79	9.87	11.41
6	2	60 539	59,800	1.163	69,540	7.15	8.22	8.28	9 69
7	0	68,415	67,450	1.147	77,360	8.50	9 60	9 91	11.30
8	1	80,747	78,800	1.153	90.950	8.33	9.38	9.68	10.66
9	2	71,644	70,200	1 169	82,070	7.96	9.12	9 42	10.63
10	0	70,148	69,300	1.154	79,980	8.49	9.64	9 84	10.76
11	0	65,430	64,570	1.157	74,710	8.80	10.05	10.16	11.77
12	1	70,273	69,070	1.159	80,060	8.38	9.55	9.70	11.69
13	2	86,194	84,370	1.189	100,320	8.06	9.38	9.48	10 79
14	1	108,763	106,580	1.176	125,350	7.75	8.94	9.00	10 10
15	0	81,018	79,790	1.155	92,160	8 82	10.04	10 11	11.59
16	2	92,423	90,390	1.182	106,840	7.33	8.47	8 53	9.52
17	3	77,857	75,820	1.193	90,450	7.17	8.33	8 39	9.53

Number of trial.	Approximate fireroom air pressure.	Chimney-gas analysis. Carbonic acid, CO_2 (per cent.).	Chimney-gas analysis. Oxygen, O (per cent.).	Chimney-gas analysis. Carbonic oxide, CO (per cent.).	Chimney-gas analysis. Nitrogen, N (per cent. by difference).	Pounds of dry gas per pound of carbon [11 (56) + 8 (57) + 7 (58) + 7 (59)] + [3 (56) + 3 (58)].	Heat balance or distribution of the heating value of the combustible. Heat absorbed by the boiler (B.T.U.'s), (44) × 965 7.	Heat balance or distribution of the heating value of the combustible. Loss due to moisture in coal (B.T.U.'s).	Heat balance or distribution of the heating value of the combustible. Loss due to the moisture formed by the burning of hydrogen (B.T.U.'s.)	Heat balance or distribution of the heating value of the combustible. Loss due to heat carried away in the dry chimney gases (B.T.U.'s).
1	8	56	57	58	59	60	61	62	63	64
1	0	9 85	6.85	1 67	81.63	21.5	9,400	7	486	2,320
2	1	9.46	6 50	1.96	82.08	21.7	9,520	8	505	2.970
3	2	12.42	4.85	1	81 73	18 7	9,190	8	566	3,930
4	0	11.08	4.75	2 19	81.98	18.8	10,870	11	492	2,290
5	1	10 35	5.03	2.20	82 42	19.8	11,020	12	487	2,400
6	2	13.77	3.73	.93	81.57	17.2	9,360	14	564	3,570
7	0	9.26	6 48	1.52	82 74	23	10,910	43	555	2,050
8	1	8.87	6.94	1.59	82.60	23.6	10,290	44	584	2,650
9	2	9.20	6.40	1.70	82 70	23 7	10,260	46	600	2,800
10	0	8.89	...	...	...	...	10,390	27	501	...
11	0	8	...	...	...	...	11,360	16	496	...
12	1	7.15	...	...	...	...	11,290	24	516	...
13	2	8.64	...	...	...	...	10,410	15	551	...
14	1	8.10	...	...	...	...	9,750	11	565	...
15	0	7.90	11.4	.90	79.80	28.1	11,190	11	521	2,740
16	2	8.90	9	1.10	81	24.8	9,190	11	577	3,880
17	3	9.70	9.1	.60	80.60	23.8	9,200	12	600	4,380

MARINE BOILER, DECEMBER 21, 1901.

Fuel per hour.						Water per hour.				
Coal as fired per hour (pounds), (33) ÷ (3).	Dry coal per hour (pounds), (33) ÷ (3).	Combustible per hour (pounds), (34) ÷ (3).	Coal as fired per hour per square foot of grate (pounds), (45) ÷ 50.14.	Dry coal per hour per square foot of grate (pounds), (46) ÷ 50.14.	Combustible per hour per square foot of grate (pounds), (47) ÷ 50.14.	Feed water per hour (pounds), (37) ÷ (3).	Water per hour corrected for quality of steam (pounds), (38) ÷ (3).	Equivalent evaporation from and at 212° F. per hour (pounds), (40) ÷ (3).	Equivalent evaporation from and at 212° F. per hour per square foot of grate (pounds), (53) ÷ 50.14.	Equivalent evaporation from and at 212° F. per hour per square foot of heating surface (pounds), (53) ÷ heating surface.
45	46	47	48	49	50	51	52	53	54	55
1,215	1,209	1,085	24.2	24.1	21.6	9,502	9,307	10,554	210	4.85
1,741	1,732	1,557	34.7	34.5	31	14,446	13,543	15,343	306	7.05
2,642	2,629	2,341	52.6	52.4	46.7	19,951	19,675	22,292	445	10.25
1,079	1,071	977	21.5	21.3	19 5	9,744	9,640	11,009	219	5.06
1,782	1,769	1,530	35·5	35·2	30 5	15,410	15,180	17,457	348	8.03
2,417	2,398	2,051	48.2	47.8	40.8	17,297	17,086	19,869	396	9.14
1,007	975	855	20.1	19.4	17	8,552	8,431	9,670	193	4.53
1,616	1,566	1,422	32 2	31 2	28.3	13,458	13,133	15,158	302	7.11
2,250	2,179	1,931	44.8	43.4	38.4	17,911	17,554	20,518	411	9 64
1,037	1,016	929	20.7	20.2	18.5	8,769	8,663	9,998	199	4.69
930	919	794	18.5	18 3	15.8	8,179	8,071	9,339	186	4.38
1,398	1,376	1,142	27 8	27.4	22.7	11,712	11,512	13,343	266	6.26
2,674	2,647	2,324	53.4	52.8	46.2	21,549	21,092	25,080	500	11.77
2,338	2,321	2,068	46 6	46.3	41 2	18,127	17,763	20,892	417	9.81
1,148	1,139	994	22 9	22.7	19.8	10,127	9,974	11,520	229	5.40
3,153	3,130	2,809	62.9	62 4	56	23,106	22,598	26,710	533	12.54
3,621	3,594	3,163	72.2	71.7	63.1	25,952	25,273	30,150	602	14.15

Heat balance or distribution of the heating value of the combustible.									Efficiency.	
Loss due to the incomplete combustion of carbon (B. T. U.'s).	Loss due to unconsumed hydrogen, etc., to heating moisture in air, to radiation, etc., (B. T. U.'s).	Heat value of one pound of combustible calculated from ultimate chemical analysis (B. T. U's).	Heat absorbed by boiler (per cent.).	Loss due to moisture in coal (per cent.).	Loss due to moisture formed by the burning of hydrogen (per cent.).	Loss due to heat carried away in the dry chimney gases (per cent.).	Loss due to incomplete combustion of carbon (per cent.).	Other losses due to radiation, etc., (per cent. by difference).	Of boiler (per cent.), (61) ÷ (67) × 100.	Of boiler and furnace (per cent.), 965.7 (43) ÷ B.T.U.'s per pound of dry coal × 100.
65	66	67	68	69	70	71	72	73	74	75
1,325	1,853	15,391	61	0.1	3.2	15.1	8.6	12	61	60
1,571	818	15,391	61.8	.1	3·3	19.3	10.2	5.3	61.8	60.8
682	1,015	15,391	59.7	.1	3·7	25 5	4 4	6.6	59.7	58 2
1,388	73	15,124	71 8	.1	3·3	15.1	9.2	.5	71.8	68.3
1,569	—364	15,124	72.8	.1	3.2	15.9	10.4	—2.4	72.8	65 6
567	1,049	15.124	62	.1	3·7	23.6	3.7	6.9	61.9	55
1,265	861	15,684	69.5	·3	3·5	13.1	8.1	5.5	69.6	64.4
1,362	754	15,684	65.6	·3	3·7	16 9	8.7	4.8	65 6	63
1,398	580	15,684	65 5	·3	3.8	17.8	8.9	3·7	65.4	61.3
.....	...	15,475	67.1	...	3.2	...	...	...	67.1	63.3
.....	...	15,475	73.4	...	3.2	...	...	...	73.4	65.4
.....	...	15,475	72.9	...	3·3	...	...	...	73	62.4
.....	...	15,475	67.2	...	3.6	...	...	...	67.2	61
.....	...	15,475	63	...	3·7	...	...	...	63	57.9
908	105	15,475	72.2	.1	3.4	17.7	5.9	.7	72.3	65
989	828	15,475	59.4	.1	3·7	25.1	6.4	5·3	59.4	54.9
519	764	15,475	59 4	.1	3·9	28.3	3.4	4.9	59 4	54

DATA SECURED DURING COAL TEST.

All the data recorded during the coal or oil tests was taken by draftsmen attached to the Bureau of Steam Engineering or by persons connected with the naval service. No reading of any gauge was recorded by any one either interested in the experimental boiler or in any appendage or auxiliary connected with the plant. There was no effort made nor desire manifested to secure results that would eclipse other records. The primary object was to secure data that would show what might be obtained in actual service.

The Board, therefore, believes that in comparing the data obtained during these experiments with any other recorded data, particular consideration should be given to the fact that during these tests all readings were made by persons who had no interest or purpose in securing specific results. It is believed that if the data recorded be carefully studied there will be conclusive circumstantial evidence adduced to show its reliability.

During some experiments there were as many as ten persons taking data, and therefore it was possible to check the readings of the gauges sufficiently often to feel assured that reliable information was being secured. The Board worked on the principle that any recorded information would be valueless unless reliable, and therefore neither trouble nor expense was spared in making arrangements for securing correct information.

INCREASED EVAPORATIVE CAPACITY SHOULD BE DEMANDED OF WATER-TUBE BOILERS OF THE STRAIGHT-TUBE TYPE.

The result of the capacity tests of the experimental boiler conclusively showed that naval administrators will be justified in prescribing that all straight-tube naval boilers should be required to burn at least 40 pounds of coal per square foot of grate per hour under forced draft, and that in order to effect such a rate of combustion the limit of air pressure may be allowed to reach $2\frac{1}{2}$ to 3 inches. By reason of the practical ability to secure increased coal combustion in marine boilers of the water-tube type the maximum I.H.P. now required of each square foot of grate surface should be increased.

The searching power of air when under several inches water

pressure was likewise conclusively shown during these experiments, for great difficulty was experienced in preventing leakage through the steel structure. These tests also showed the advisability of ascertaining whether it is possible to maintain 2 inches of forced-draft pressure for several continuous hours in all the compartments of a battleship while securing the capacity and efficiency of evaporation that should accompany such high air pressure. Greater air pressure has been carried in boiler compartments, but careful investigation shows that at such times the fires were so thick that the coal consumption seldom exceeded 40 pounds per square foot of grate. It will be found in practice that the limit to which the entire boiler plant of a warship can be forced is quite different from results secured when the entire fireroom complement and all the blowers are employed in experimental work upon a few boilers.

THE PROBLEM OF THE WATER-TUBE BOILER.

As the Board was originally appointed to determine the value of the Hohenstein boiler for naval purposes, as well as to conduct experiments wherein definite data could be secured relating to the naval-boiler problem, special observation was made as to the endurance of this type of boiler when using both coal and oil.

The boiler problem is of such importance in maritime matters that the solution of the fuel question is intimately connected with the design of the steam generator.

The following extract from the report of the Engineer in Chief of the Navy, Rear Admiral George W. Melville, U. S. Navy, for the fiscal year ending June 30, 1902, so succinctly states the importance of the boiler problem in naval warfare that the Liquid Fuel Board incorporates these views as reflecting its general opinions upon the importance of installing an approved type of boiler that will possess both economical efficiency and endurance under severe forced-draft conditions.

THE PROBLEM OF THE WATER-TUBE BOILER—THE HOHENSTEIN BOILER TRIALS.

The present problem of the modern battleship is not that of the gun and its mount, but the boiler and its installation. The

gun is mounted in the most favorable position for care, operation and inspection, and practically everything on board ship is subordinated to its efficient working. Since a large factor of safety is given to every part of the weapon that is subjected to shock, the gun can only be impaired by incompetence, neglect, or by chemical action of the explosive. Before it is placed in a turret or redoubt it is fully tested, but it is never put on board ship if there is a suspicion that it has been subject to undue strain.

The boiler, on the other hand, is placed beneath the protective deck just above the bilges and near the bunkers. It is installed in compartments that are avoided rather than sought by other than engineer officers. While a careful test is made of the structure before being placed in the vessel, it must necessarily be subjected, even before installation, to conditions that often impair its strength. In its construction many of the plates are subjected to the severest kind of flanging, and its efficient inspection is much more difficult than that of the gun. As there has been a progressive demand for increased steam pressures, the factors of safety used in designing a marine boiler are progressively becoming smaller. The conditions under which the boiler is operated necessarily cause some of the parts to be subjected to rapid corrosion, and only incessant care and attention can prevent the disablement or rupture of the structure.

The experience of the United States Navy with the boilers of the torpedo boats and torpedo-boat destroyers ought to afford some startling evidence as to the manner in which incompetent or untrained men can impair or destroy the efficiency of these steam generators. The agitation in Great Britain over the navy-boiler question ought also to convince naval administrators that the boiler problem is the naval problem of the hour.

In view of the British experience with the Belleville boiler, it is not surprising that the general public of that empire regard the boiler commission now in session as one of the most important boards appointed by the Admiralty during the past ten years. The membership of this board comprises distinguished experts within and without the naval service. This board has been in session nearly two years investigating the question as to which

type of marine boiler is most suitable for use in the Navy as the one of approved design. The Admiralty regard the solution of this problem as of vital importance to the efficiency of the British fleet. A series of evaporative and endurance tests of various types of boilers have been made, and the more carefully the question is investigated the more important does it appear in relation to the operation of a modern navy.

The work of the British boiler commission will have a very important influence upon naval construction, since it will cause thoughtful experts to give more attention to the design, construction, installation and operation of the boiler. One must have experience in the operation of a modern marine boiler to appreciate the intelligence, skill and care that must be devoted in keeping it in a state of efficiency. The boilers are the lungs of a vessel, although this fact is not generally understood.

While the war ship may be nothing more than a gun platform, it requires considerable power to move a platform of 14,500 tons at a high speed in a heavy sea. This platform is not only expected to be maneuvered rapidly, but to steam uninterruptedly for a distance of one-fourth the way round the world. The battleship that can not make the enemy's coast the first line of defense is limited in the field of its usefulness, and when operating at such distance the value of the boiler factor comes only second to the value of the factor of the gun.

The efficiency of the war ship of the several naval powers is simply proportionate to the efficiency of their boilers and the character of their personnel. Neither in armor, armament or machinery is there any vital difference between the battleships of the several nations. In these respects, the last ship, wherever designed, is the best, for as regards draught, tonnage, thickness and extent of armor, character and distribution of guns, and design of machinery, every nation has settled upon a type of vessel that meets its particular requirements, and each navy has therefore secured the best warship for its particular purpose.

The boiler problem, however, has been unsolved. Without taking into consideration the question of personnel, the value of the warships of the different naval powers can be measured by

the efficiency and endurance of the steam generator installed in the vessel. This fact may not be appreciated in its fulness at the present time, but the experience of the coming five years with the ships nearing completion will conclusively show that in coming naval conflicts the question of victory may be quite as much dependent upon the battle of the boilers as the contest between the guns.

With a deep appreciation of the necessity of soon settling upon an approved type of marine boiler for the battleships and armored cruisers of the United States Navy, the Bureau has invited competition among designers. It believes, however, that, if possible, a boiler of American design should be adopted, and that this marine boiler should be a development of one in general use on shore. By seeking a design that is familiar to thousands of firemen on shore, an important military advantage would be secured, since in time of emergency there could thus be recruited for the naval service water tenders and firemen who had operated almost similar steam generators, and who would therefore require but little training to familiarize themselves with the duty on board ship. While the Navy can and ought to do some efficient work in training firemen, it would be very advantageous to the service if the enlisted force in the stokeholes could have considerable preliminary training with boilers of nearly like design to the one in most extensive use as the approved type for the Navy.

About two years ago the Bureau was informed that an American boiler firm, with considerable financial backing, desired to enter the field of marine-boiler construction. In keeping with the Bureau's policy of inviting competition, encouragement was therefore given the Oil City Boiler Works to design and build a marine boiler and turn it over to the Bureau for test as to its evaporative efficiency and endurance.

The question of entering upon the field of marine-boiler construction had been carefully considered by the Oil City Boiler Works. As the officials of that establishment believed that the time was not far distant when there would be a large demand for marine water-tube boilers, they volunteered to equip an experi-

mental plant at the company's expense. The boiler was of sufficient size to thoroughly test its adaptability for naval purposes. There was therefore constructed a steam generator whose limitations as to weight, height and floor space were similar to the conditions prescribed for the cruiser *Denver*, and these conditions are, in many respects, the most severe that have been exacted by the Department. Eighteen months ago the experimental plant was completed, and there was placed at the disposal of the Bureau a boiler of the Hohenstein design.

It was well understood before the Bureau undertook to experiment with this boiler that the character and extent of the data to be collected were to be entirely determined by officials of the Government. In justice to the Oil City Boiler Works it should be stated that every suggestion of the Department was carried out, and that it was the evident purpose of the company to accurately ascertain the requirements of the Bureau, and to discover the greatest difficulties that were likely to be experienced in meeting naval demands. Stated in a business way, the company was willing to expend from fifty to one hundred thousand dollars to ascertain whether or not it would be advisable to extend their plant to enter the field of marine-boiler construction.

In many respects the experimental plant was one of the most complete that has ever been established. The series of tests conducted will command attention in the engineering world, for absolute information has been obtained as to the evaporative efficiency and endurance of the boiler. Information has also been secured in regard to the best means of baffling the gases, thus increasing the evaporative efficiency as well as permitting the boiler to be forced for emergency purposes. Particular care has also been given by the Board to the investigation of the circulation of the water, for probably the key to the boiler problem is the question of circulation.

While only seventeen official tests were made with coal as fuel, there were a great many unofficial experiments. Between the several official tests the experts of the Oil City Boiler Works conferred with the Bureau, and therefore each test represents the result of study and experiment. An examination of the data will

conclusively show that in many respects the completeness and character of the tests have never been surpassed.

The first six coal tests were run by a picked crew of firemen who had experience in torpedo-boat work. It was believed that these men by training and experience were particularly well fitted to operate the boiler when under severe forced-draft conditions. An experience of a few weeks with this force showed that new methods in firing had to be employed in efficiently operating water-tube boilers, and that the best means of securing efficient work was to have skill and intelligence from those in charge of the fireroom and implicit obedience upon the part of the subordinates. The remaining eleven tests were thus made by firemen living in the city, not one of whom had ever before worked a boiler under forced-draft conditions. The second set of firemen implicitly obeyed orders, and it was therefore possible for the Board to have its instructions carried out. A uniform pressure of steam was maintained, as well as a regularity in firing, that was productive of good results.

The data secured can be regarded as reliable, for checks and counterchecks were used so that the Bureau could be placed in possession of information that could be relied upon as to completeness and accuracy.

In view of the present condition of this experimental boiler after eighteen months of use with both coal and oil as a combustible, considering the results secured, and by reason of the report submitted by the Board which conducted the series of tests, the Bureau has no hesitation in regarding the boiler as the equal in efficiency and endurance of any used in a foreign battleship.

* * * *

FUEL OIL TESTS.

THE EXPERIMENTAL PLANT THOROUGHLY OVERHAULED BEFORE COMMENCING LIQUID-FUEL TESTS.

Upon the completion of the coal tests the experimental boiler and various auxiliaries connected with the installation were thoroughly overhauled, so that the plant could be put in condi-

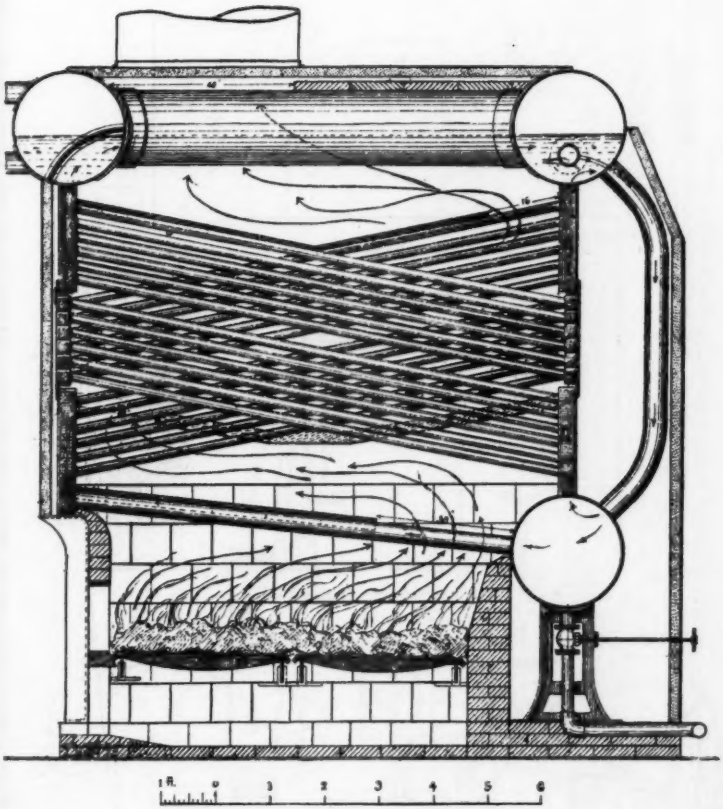


Fig. 1.—The Hohenstein Experimental Boiler used in the Naval Tests, Arranged for Coal Burning.

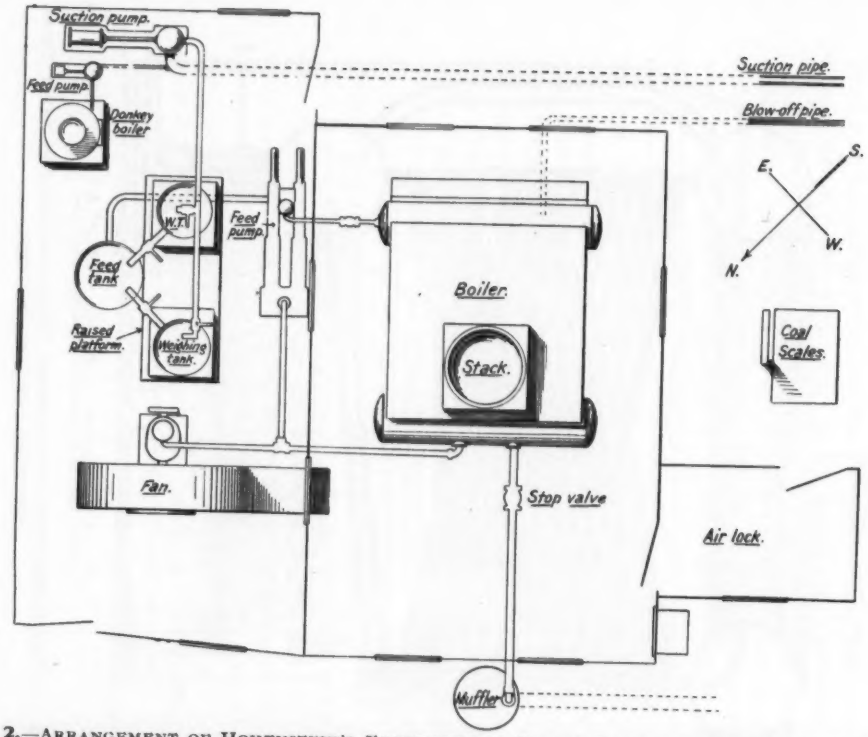


Fig. 2.—Arrangement of Hohenstein's Experimental Boiler Plant for Coal-Burning Tests.

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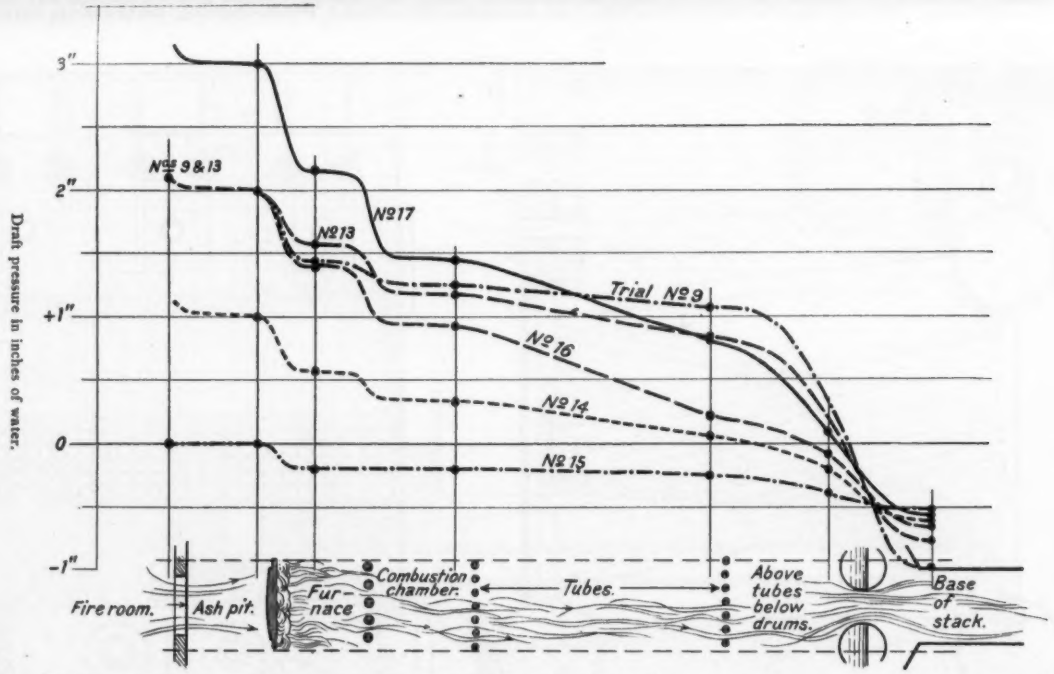


Fig. 3.—Curves Showing Variation of Air Pressure within the Boiler during certain Coal-Burning Trials. Spots Indicate Points where Measurements were made.

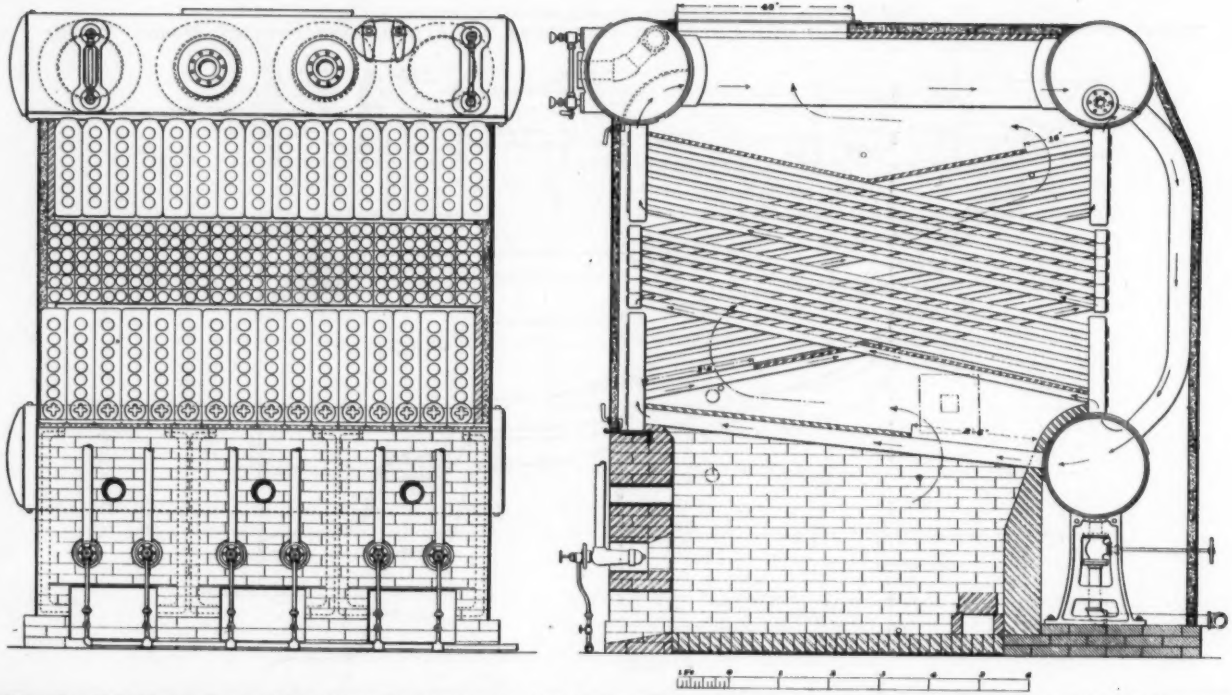


Fig. 5.—The Hohenstein Experimental Boiler as Arranged for the Naval Liquid-Fuel Trials. Draft Gauge Connections are Shown by the Small Circles, o ; Mica Windows, or Peep Holes, are Shown by Larger Circles, O.

Fig. 5.—The Hohenstein Experimental Boiler as Arranged for the Naval Liquid-Fuel Trials. Draft Gauge Connections are Shown by the Small Circles, ○; Mica Windows, or Peep Holes, are Shown by Larger Circles, ○.

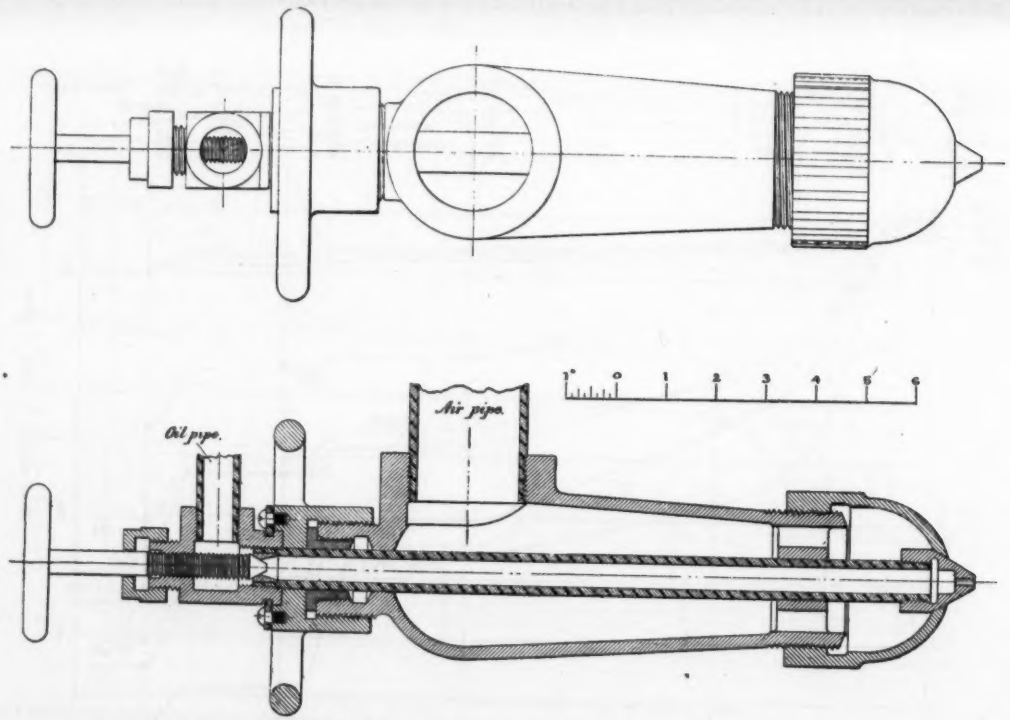
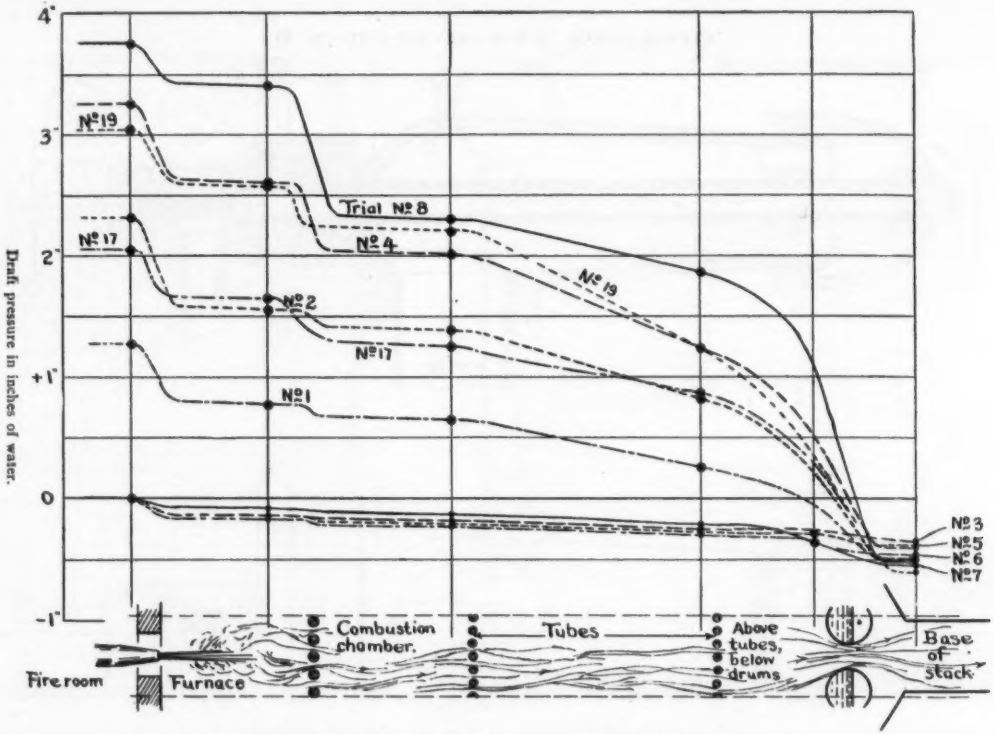
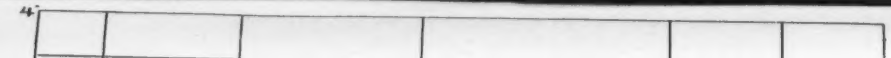


Fig. 6.—The Oil City Boiler Works Burner.



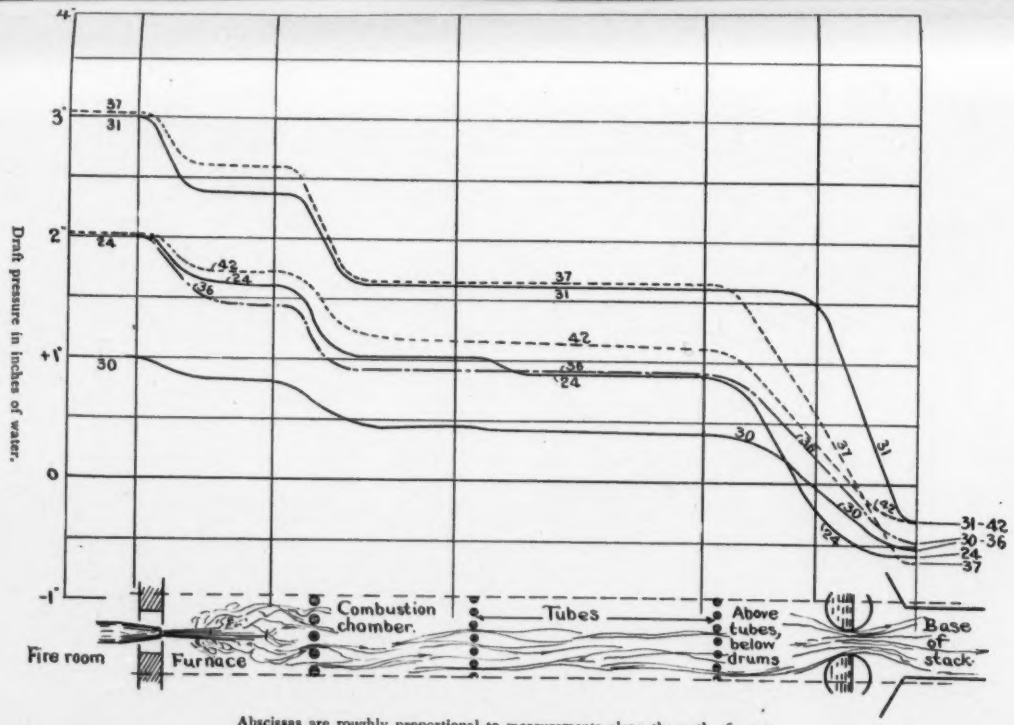
Abscissas are roughly proportional to measurements along the path of gases.

Fig. 7.—CURVES SHOWING VARIATION OF AIR PRESSURE WITHIN THE BOILER DURING CERTAIN OIL-BURNING TRIALS. SPOTS INDICATE POINTS WHERE MEASUREMENTS WERE MADE.



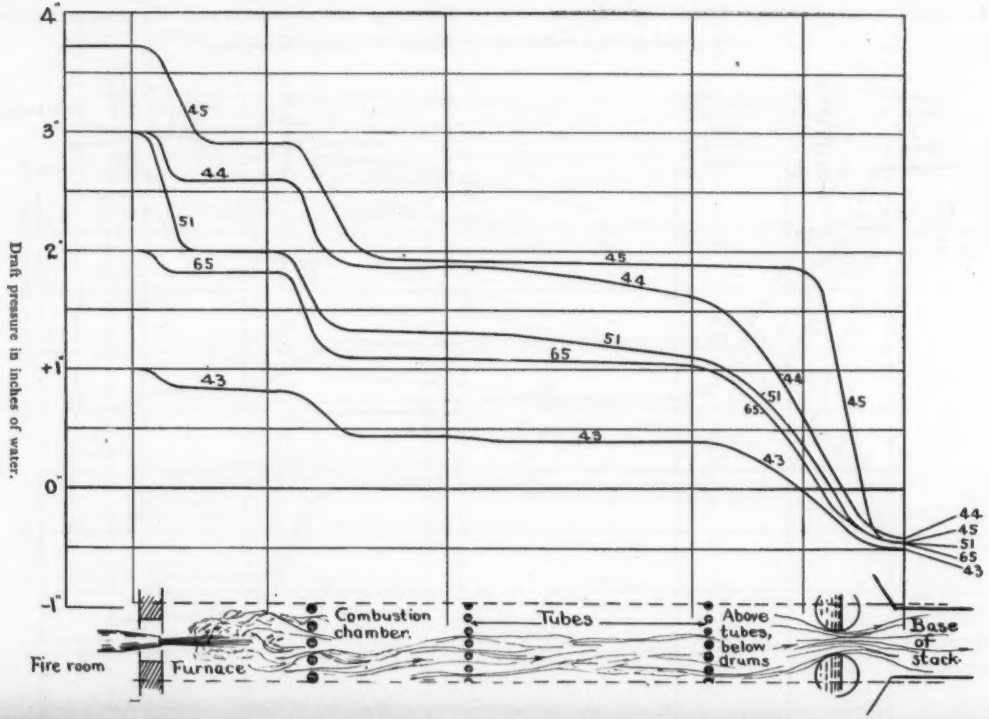
Abscissas are roughly proportional to measurements along the path of gases.

Fig. 7.—Curves Showing Variation of Air Pressure within the Boiler during certain Oil-Burning Trials. Spots Indicate Points where Measurements were made.



Abscissas are roughly proportional to measurements along the path of gases.

Fig. 8.—Curves Showing Variation of Air Pressure within the Boiler during certain Oil-Burning Trials.



Abscissas are roughly proportional to measurements along the path of gases.

FIG. 9.—CURVES SHOWING VARIATION OF AIR PRESSURE WITHIN THE BOILER DURING CERTAIN OIL-BURNING TRIALS.

Abscissas are roughly proportional to measurements along the path of gases.

Fig. 9.—Curves Showing Variation of Air Pressure within the Boiler during certain Oil-Burning Trials.

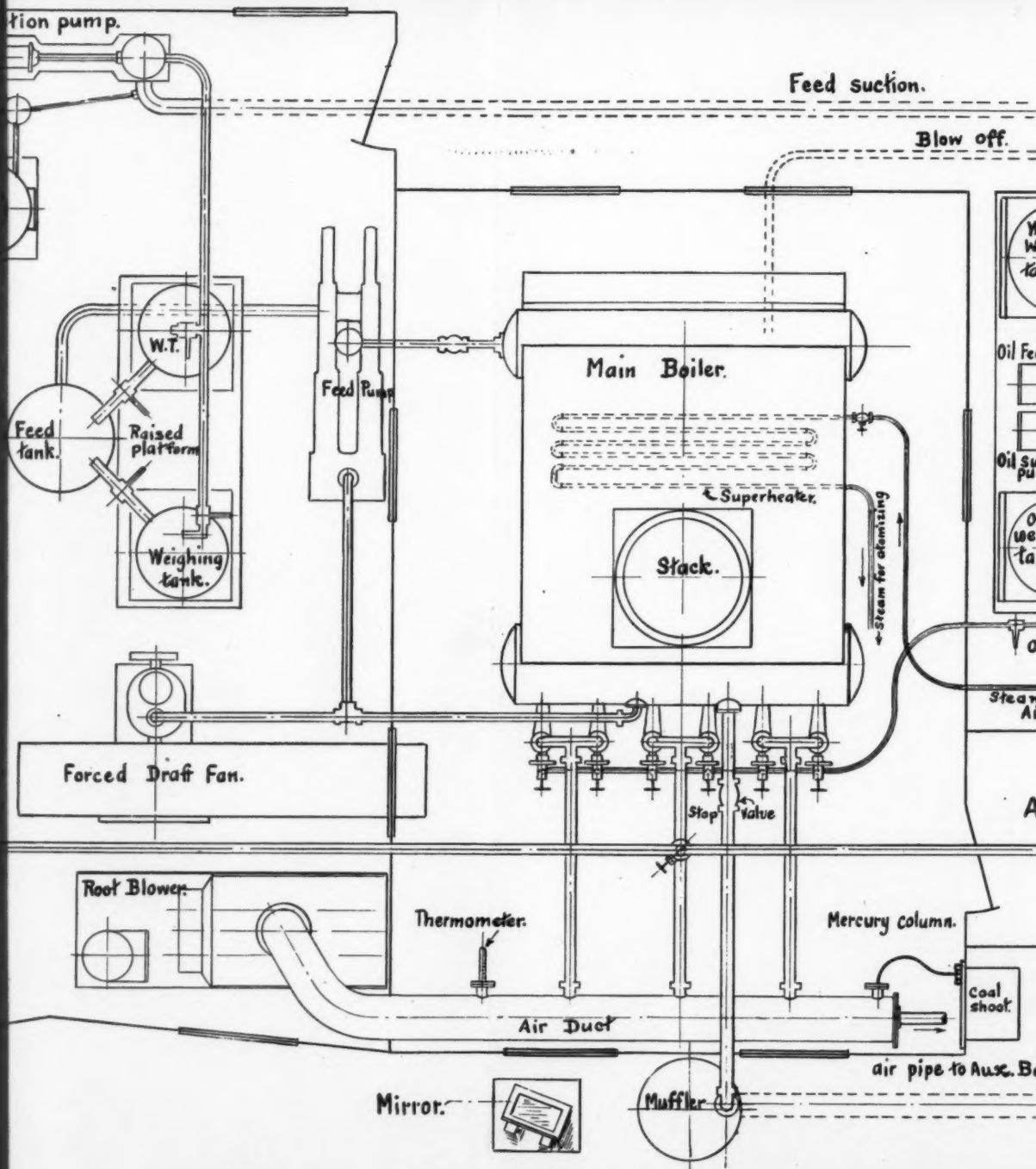
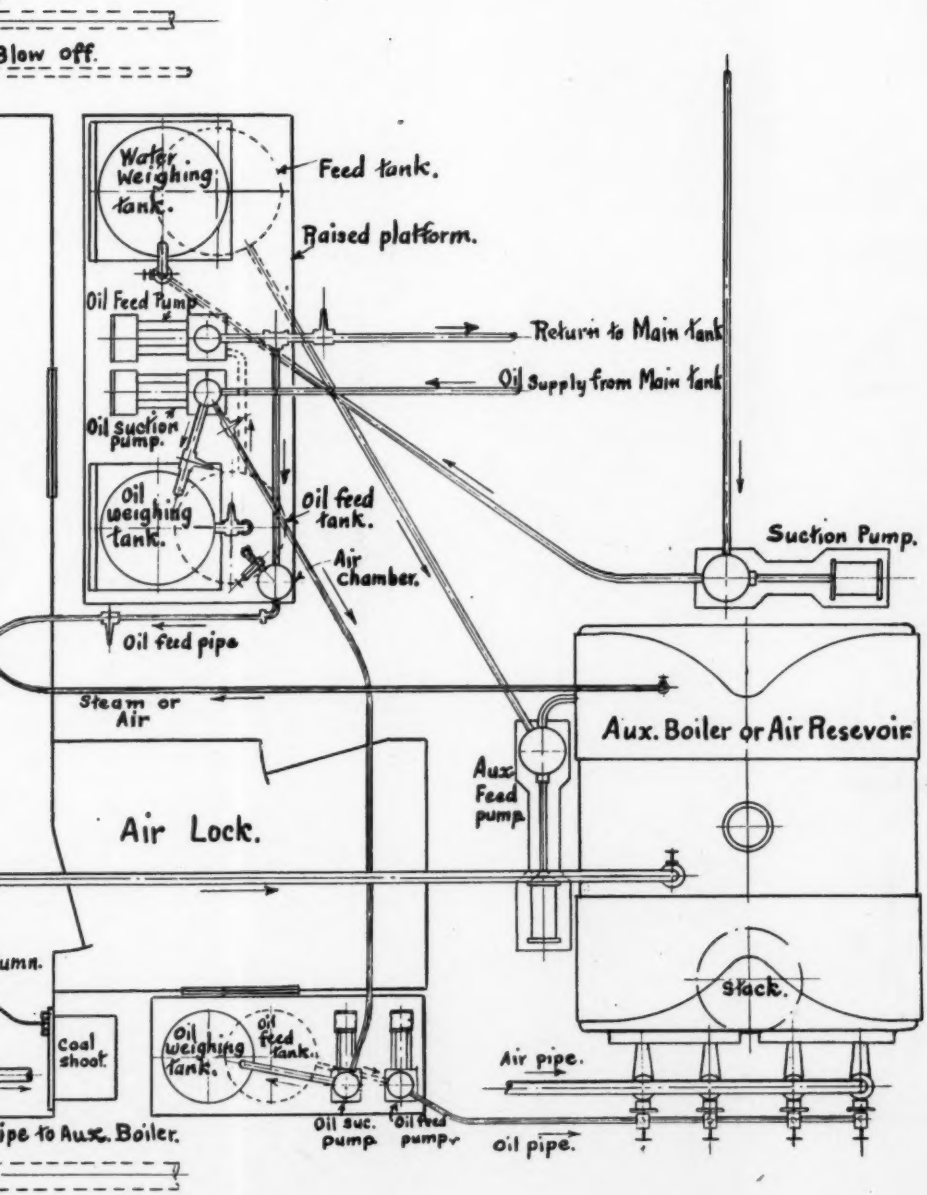


Fig. 4.—General Arrangement of the Hohenstein Experimental Boiler Plant for Liquid



NT FOR LIQUID-FUEL TESTS.

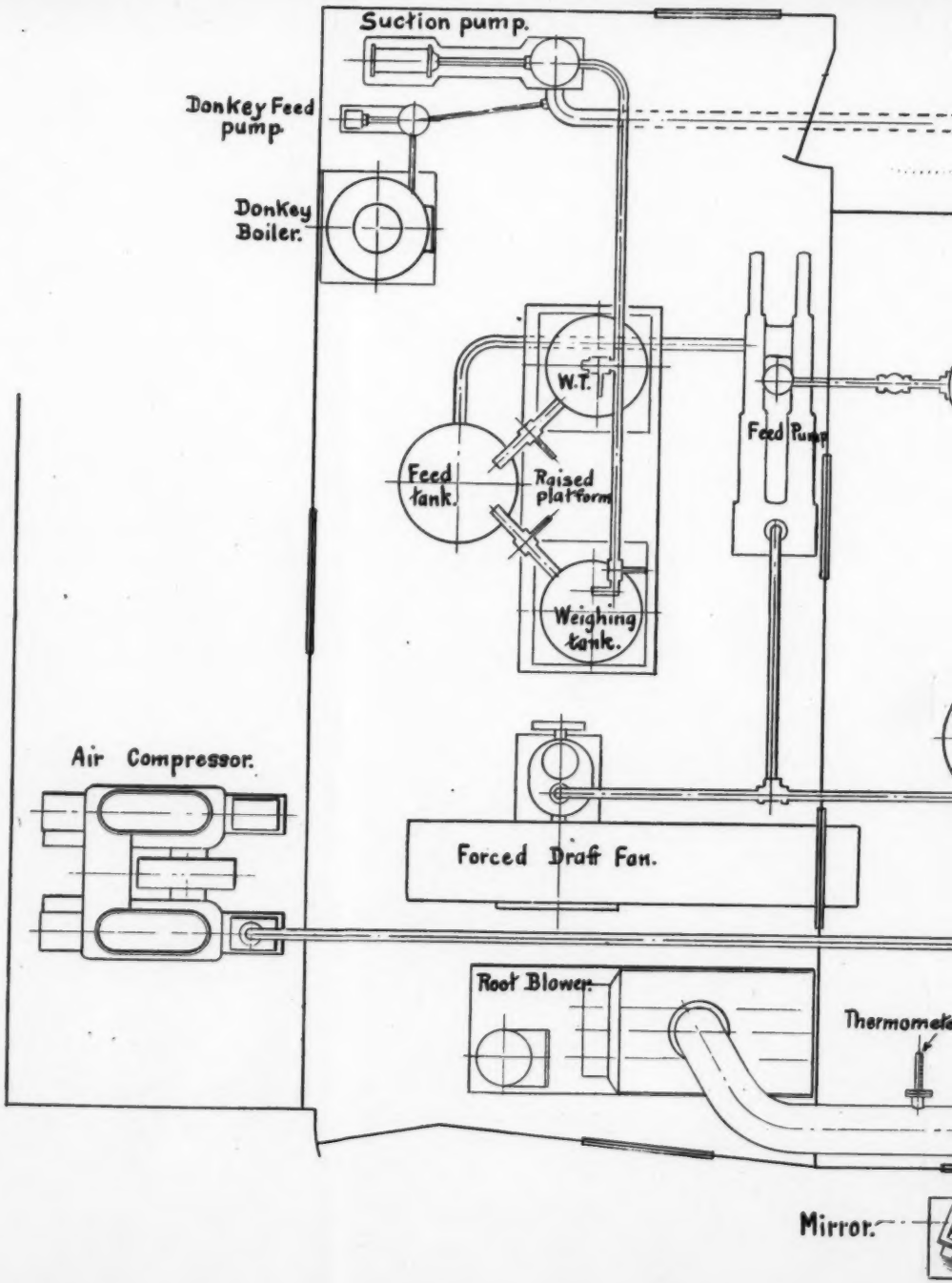
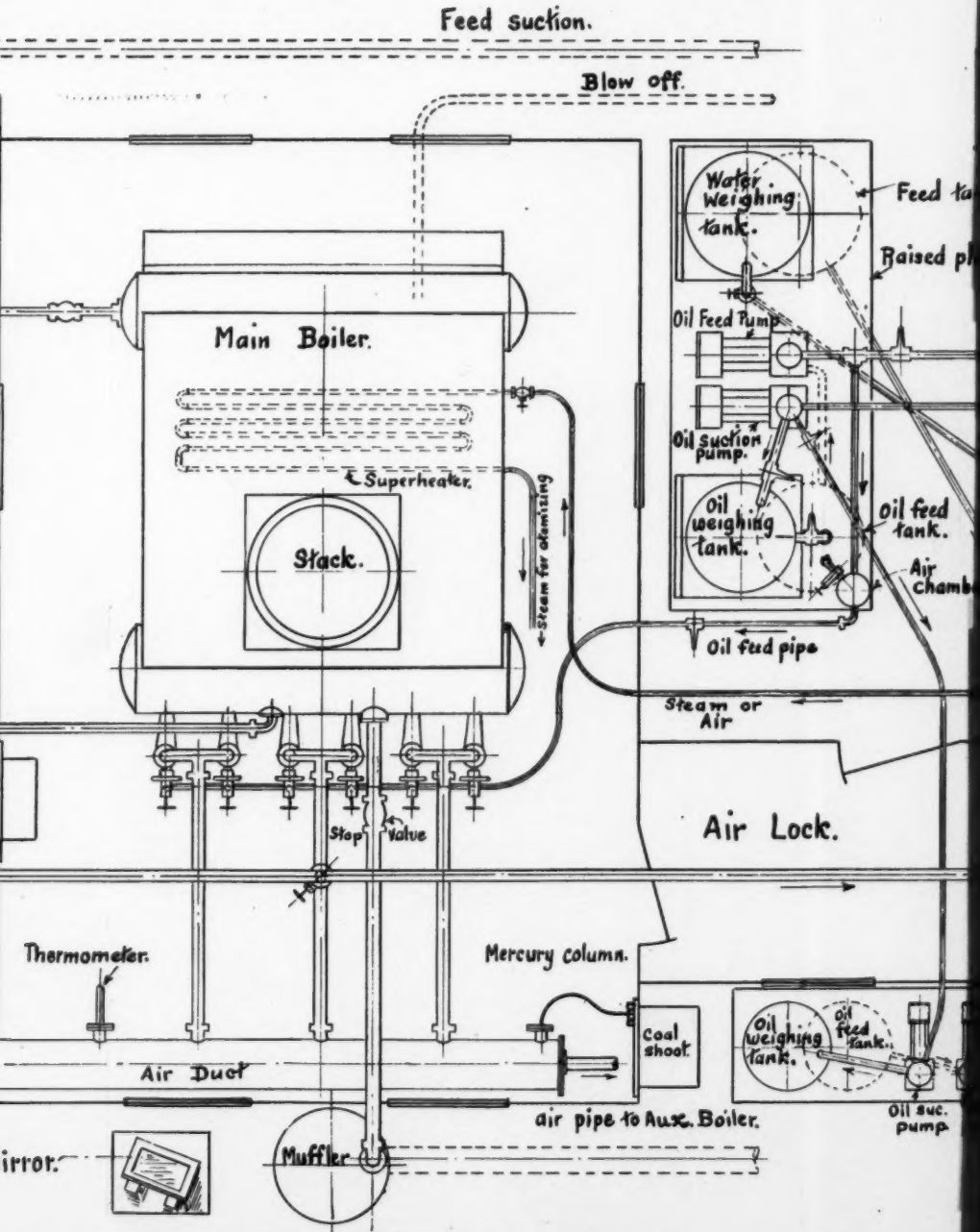


Fig. 4.—General Arrangement o



RRANGEMENT OF THE HOHENSTEIN EXPERIMENTAL BOILER PLANT FOR LIQUID-FUEL TESTS.

tion for carrying on the extended series of liquid-fuel tests contemplated by the Bureau for years, and which were authorized by the naval appropriation bill enacted into law July 3, 1902.

Preparatory to commencing the oil tests the boiler was opened, cleaned, and thoroughly examined. The baffling and lining were renewed where necessary. A cylindrical tank boiler for furnishing steam for spraying purposes was installed, as well as a new compressor capable of delivering air if required at a very high pressure for a spraying medium. An asbestos lining was put underneath the fire brick of the furnace floor.

Close observation was made as to the condition of the tubes. It was found that none of them had buckled or sprung, and, with some trifling exceptions, there were no noticeable leaks nor weeping of seams, rivets or tube ends.

While the official coal experiments only continued for about nine months, the experts of the Oil City Boiler Works had been making preliminary tests for a considerable period, previous to the commencement of the official coal experiments. The boiler had thus been subjected to continuous, varied, and at times severe strain for over a year in the conduct of the coal experiments. Particular care was taken before commencing the coal tests to note the condition of every part of the boiler liable to give trouble, so that a fair comparison of the effect of using coal and oil as a fuel could be made.

GENERAL DESCRIPTION OF THE EXPERIMENTAL PLANT WHEN BURNING OIL FUEL.

Fig. 4 is a ground plan of the plant.

Fig. 5 shows the longitudinal section of the experimental boiler with the oil burners in place.

The Oil City Boiler Works Company's design of burner (Fig. 6) was used during thirty-three tests, the remarks of each official test showing the manner in which its installation was modified and changes made in details of construction. Six of these burners, spaced 18 inches apart, were ranged across the front of the furnace, there being a separate opening in the furnace walls for each burner. Provision was made whereby air could be admitted

through the holes as well as through the ash pit. Considering the burners as arranged in three pairs, those of each pair were inclined toward each other at such an angle that their flame impinged near the transverse center line of the furnace.

The burners were so installed that any one could be quickly disconnected or overhauled, and at a height that would make their manipulation by the water tenders comparatively easy. Special precautions were taken that all oil-fuel joints were made tight and that no loss would result from leakage.

The arrangements for weighing the feed water were substantially the same as during the coal-burning tests. The facilities for securing various degrees of forced draft were identical with the conditions existing when coal was burned in the furnaces.

METHOD OF WEIGHING OIL USED.

From the storage tank the oil was pumped as desired into a weighing tank, from which it flowed by gravity into the oil-feed tank. From this reservoir the oil was pumped into a pipe leading to the burners, constancy of the pressure being secured by an air chamber and a relief valve. An overflow pipe led from a relief valve back to the feed tank. The weighing and feed tanks were fitted with gauge glasses graduated to 5 pounds, by the aid of which the exact weight of oil was secured at the end of each hour, the same as with the feed water.

The air for atomizing the oil was supplied by a Root blower driven by a direct-connected engine. This blower delivered 8 cubic feet of free air per revolution, at pressures ranging from 0.78 pound to 4.68 pounds per square inch. The air pressure was measured by a mercury column, the location of which was such that it gave substantially the same pressure as at the discharge of the blower. The temperature of the compressed air was taken near the same point. A Rand air compressor was also installed, thus enabling higher pressures of air to be used.

The process of getting up steam in the main boiler was somewhat slow, as dependence had to be placed on a small auxiliary boiler for driving the Root blower until sufficient steam pressure could be secured for that purpose from the main boiler. The

auxiliary boiler was only equal to the task of supplying the air to two burners.

CHARACTER OF THE OIL USED.

While the Bureau received many offers from various sources to furnish oil free of cost at the wells, careful inquiry showed that there was no certainty when this oil could be delivered at the experimental plant. Since time is a great element in the matter, the Board deemed it necessary to use means whereby a steady supply of oil would be assured and no delay ensue from a lack of liquid fuel in the storage tank. The oil was therefore secured from the Standard Oil Company.

The oil used during most of the experiments was from the Beaumont, Tex., field. It is said to have been subjected to an inexpensive treatment which removed the sulphur and some of the more volatile hydrocarbons. The Board believed that it would be best to use an oil that had been thus treated until some positive information could be secured as to whether or not it was safe and advisable to attempt to use crude oil. It should also be stated that delay might have ensued if it had been attempted to depend upon individual shipments. The judgment of the Bureau in this respect was vindicated, for there were times during the tests when others in the city were unable to secure any oil at any price.

CONDITIONS BETWEEN THE COMBUSTION CHAMBER AND SMOKESTACK.

The temperatures in the base of the stack during the oil tests were remarkably free from the rapid fluctuations that characterized the coal-burning trials. There was seldom flaming in the stack, and even then the fluctuations of temperature were absent. The stack temperatures were noted by a mercury-nitrogen thermometer. It was used without mishap throughout the series of trials. Advantage was taken of the constancy of the stack temperature to check the readings of a Brown quick-reading pyrometer. The pyrometer was afterwards used in the furnace and elsewhere to record temperatures that were not excessive. For temperatures higher than 1,600 degrees Fahrenheit a platinum-rhodium electric pyrometer was used. The measurements secured

with this instrument show a maximum furnace temperature of 2,200 degrees Fahrenheit for both natural and forced-draft conditions.

The draft pressures were measured at the same points as in the series of coal-burning tests, and the average readings are shown diagrammatically in Figures 7, 8 and 9.

As an aid to the proper regulation of the supply of oil and air to the burners, a mirror was so placed that the man in charge of the fireroom could quickly note the color of the gases that issued from the top of the stack. The Board considered it of great importance that those operating an oil-fuel installation should possess some device whereby the condition of affairs at the top of the stack can be immediately ascertained.

After considerable study and discussion, it was decided that it would be best to give each burner an excess of oil, and this would be shown by the smoke issuing from the stack. Then there was a gradual reduction of the quantity of oil until just a faint trace of smoke could be noticed.

Provision was made for introducing extra air at the sides of the furnace during some of the experiments. Holes were cut 8 inches by 1½ inches through the side walls, on a level with the furnace floor and close to its back wall. A flue was built of loose fire brick across the furnace floor, thus connecting the two openings. The roof of the flue had openings between the bricks, thus permitting extra air to be introduced where the combustion was most intense. This extra air supply was cut off during the natural-draft and maximum forced-draft trials. The aggregate area of all openings for the admission of atmospheric air into the furnace is given in the detailed report of each trial.

ENDURANCE TEST OF 116 HOURS.

The Board particularly deemed it expedient to make an endurance test of the plant. (See Table 6.) A test of this nature was therefore conducted for a continuous period of 116 hours. The torpedo boat *Gwin* was ordered from the Naval Academy, and the torpedo boat *Rodgers* from Norfolk, to assist in the experiments. The day watch of eight hours was conducted by a reg-

ular crew of employees of the Oil City Boiler Works, although all the data during this period was taken by observers from the drafting-room staff of the Bureau of Steam Engineering. The crew of the *Gwin* operated the boiler and auxiliaries during half the night, the crew of the *Rodgers* taking the other night watch during the entire test. The data during the night was taken by the leading petty officers of the two torpedo boats, the commissioned and warrant officers in charge of the respective watches checking and verifying the data. The character of the records collected during the night, compared with that secured during the day, shows the material efficiency of the crews of the torpedo boats even as compared with the highly trained force of draftsmen in the Bureau of Steam Engineering.

The test was conducted under the general supervision of the Oil-Fuel Board. The following four commissioned officers had entire charge of the crews and observers during successive watches: Lieut. A. M. Procter, United States Navy; Lieut. G. S. Lincoln, United States Navy; Lieut. Wm. R. White, United States Navy; Lieut. John Halligan, Jr., United States Navy. These officers not only supervised the work of the entire watch, but checked the data.

Four warrant machinists, Messrs. Steele, Johnson, Schreiber and Rowe, were detailed to assist the commissioned officers. These warrant officers were placed in charge of the fireroom.

After a preliminary run for the purpose of training officers and crews in taking data and operating the plant, the test was commenced at noon on August 4. Experts from the Oil City Boiler Works and from the fuel-oil department of the Standard Oil Company were present during each day, and at times visited the plant at night. The members of the Board, the commissioned officers in charge of the watches, the warrant machinists in the firerooms, as well as the enlisted force of the torpedo boats availed themselves of the opportunity to secure advice and assistance from these experts, who, by reason of their training, experience and opportunity are and ought to be particularly well posted upon the subject. After the first day it was seldom that these experts even offered a suggestion as to operating the

burners. They declared that the commissioned officers in charge of the watch and the warrant machinists took such interest in the work and had so quickly grasped the salient points of effecting complete combustion of petroleum as a fuel that it was best to turn over the plant to the sole management of such observing and skilled officers.

The oil burners used during the endurance test were so regulated that they consumed about 830 pounds of oil per hour. Although the data were only recorded at hourly intervals throughout the test, there were unofficial readings and checks made between the hours, thus noting whether uniformity was maintained in the performance of the boiler.

* * * * *

The smoke issuing from the stack was quite light and uniform in color. From the records of ten observations made during the day watches it appears that the maximum variation was from 0 to 1 by Ringelmann's charts, the average color throughout the day being 0.4.

Temperatures taken with a platinum-rhodium pyrometer showed 1,980 degrees Fahrenheit near the middle of the furnace. At the receiving end of the combustion chamber the temperature was 1,900 degrees Fahrenheit.

Toward the end of the test the water in the boiler became very muddy. It should be stated that during the entire endurance trial the boiler was fed with Potomac river water that had not been filtered. It might also be stated that during the past eighteen months the experimental boiler has been subjected to just this kind of work, using a quality of water which would have been rejected by many other boiler users. The notes appended to the coal and oil tests will show in detail the treatment the boiler received. Occasionally the gauge-glass connections would get clogged with mud, and toward the end of the endurance test it was necessary to blow steam through them every half hour.

Two pieces of carbon were removed from the vicinity of the second burner from the left: one piece on August 7 and the other on August 9. Each piece was about 64 cubic inches, and

was caused by the burner being so placed as to permit the flame to impinge on the brickwork of the front furnace wall.

CHEMICAL COMPOSITION OF THE OIL USED DURING TESTS COMPARED WITH THE CRUDE PRODUCT.

The character of the oil used during the official tests can be best appreciated by comparing it with the average grade of the crude product. The changes wrought by the refining process can thus be clearly seen by comparing the analyses of the crude Beaumont product and that used in the experiments.

ANALYSIS OF BEAUMONT CRUDE OIL.

	Per cent.
Carbon (C)	84.60
Hydrogen (H)	10.90
Sulphur (S)	1.63
Oxygen (O)	2.87

The amount of sulphur in different samples of the crude Beaumont oil varies from 2 to 3 per cent.

Calorific value per pound of combustible, B. T. U	19,060
Specific gravity	0.924
Flash point, degrees Fahrenheit	180
Fire point, degrees Fahrenheit	200

On distillation at atmospheric pressure to 524 degrees Fahrenheit it was found that the—

	Degrees F.
First 10 per cent. passed over below	428
Second 10 per cent. passed over between	428 and 485
Third 10 per cent. passed over between	485 and 524
Fourth 10 per cent. passed over between	524 and 554

ANALYSIS OF BEAUMONT OIL USED BY LIQUID-FUEL BOARD AS DETERMINED BY THE CHEMIST OF THE NAVY YARD, NEW YORK.

On distillation at atmospheric pressure to 680 degrees Fahrenheit it was found that with the oil used during the tests—

	Degrees F.
First 10 per cent. passed over between	216 and 482
Second 10 per cent. passed over between	482 and 523
Third 10 per cent. passed over between	523 and 552
Fourth 10 per cent. passed over between	552 and 680

This oil showed on analysis to be composed of the following constituents:

	Per cent.
Carbon (C)	83.26
Hydrogen (H)	12.41
Sulphur (S)	.50
Oxygen (O)	3.83

The sulphur was determined by oxidation with fuming nitric acid in an open capsule.

Specific gravity at 60 degrees Fahrenheit	0.926
Flash point, degrees Fahrenheit	216
Fire point, degrees Fahrenheit	240
Vaporization point, degrees Fahrenheit	142
Loss for six hours at 212 degrees Fahrenheit, per cent	21.65

The calorific value of the combustible, calculated on the analysis of the United States Chemist by Dulong's formula, viz:

$$\text{British thermal units} = 14500\,C + 62100\,(H - O/8)$$
$$= 19481.$$

These analyses show that nearly all the sulphur was removed from the crude petroleum.

ANALYSIS OF CALIFORNIA OIL USED BY LIQUID-FUEL BOARD AS DETERMINED BY CHEMIST, NAVY YARD, NEW YORK.

The sample consisted principally of high-boiling hydrocarbon compound with a small amount of water, and has the ultimate composition:

	Per cent.
Carbon	81.52
Hydrogen	11.01
Sulphur	.55
Nitrogen, Oxygen	6.92

It gives the following constants:

Calorific value by Parr's calorimeter, B. T. U	18,667
Specific gravity at 60 degrees Fahrenheit	0.966
Vaporization point, degrees Fahrenheit	230
Flash and burning point, degrees Fahrenheit	311
Loss for six hours at 212 degrees Fahrenheit, per cent	12.20

ANALYSIS OF RESIDUUM MIXTURE OF CALIFORNIA AND TEXAS OILS.

The oil used during tests Nos. 68 and 69 was the dregs of the tank, and consisted of a mixture of the California and Texas product. As it has been maintained by some experts that trouble would be encountered in using this mixture, special observation was made as to the manner in which it would burn.

It would also be a matter of interest to consumers of oil to note the evaporative efficiency of such fuel. An analysis of this mixture, as made by the chemist of the navy yard, New York, gave the following results:

	Per cent.
Carbon	84.35
Hydrogen	11.33
Nitrogen	.60
Sulphur	.90
Oxygen	2.82

On distillation the following percentages passed over:

	Per cent.
Between 400 degrees and 450 degrees Fahrenheit	8
Between 450 degrees and 580 degrees Fahrenheit	12
Between 580 degrees and 600 degrees Fahrenheit	30

It has the following constants:

Calorific value by Parr's calorimeter, B. T. U.	19,215
Specific gravity at 60 degrees Fahrenheit	0.966
Vaporization point, degrees Fahrenheit	130
Flash point, degrees Fahrenheit	270
Burning point, degrees Fahrenheit	280
Loss for twenty-four hours at 212 degrees Fahrenheit, per cent	14.90

* * * *

PROGRESSIVE TESTS WITH STEAM ATOMIZING BURNERS.

These tests were made September 19, 20 and 22. One of the special purposes of conducting these trials was to ascertain the exact amount of steam that would be required for atomizing the oil. Every possible check was used to secure trustworthy data. All during the trials there were searches for leaks, but none were discovered.

To ascertain just how much steam was required for atomizing, a separate boiler was installed for generating steam for this pur-

pose. This is a cylindrical return-tube boiler with two plain cylindrical furnaces; is piped to furnish steam for the oil burners, and has no other steam pipe leading from it. The opening from the safety valve was blanked. This boiler is fitted with two oil burners of Oil City Boiler Works design in each furnace, these burners using air for atomizing purposes. After steam was raised one burner in one furnace was found sufficient to keep the steam pressure uniform.

This auxiliary boiler was put in thorough order at the Navy Yard, New York, and carefully made tight at 100 pounds pressure. During the oil-burning test great care was taken to keep both the water level and the steam pressures in this boiler uniform. The water used was carefully weighed in a separate weighing apparatus, in exactly the same manner as the water supplied to the experimental boiler.

The pressure for atomizing purposes in the burners of the experimental boiler, as well as the pressure at which the oil was forced to the burners, was increased each day. It was found that the higher the pressure the greater the amount of water that was evaporated in the main boiler. The efficiency was also slightly greater as higher pressures were used. The percentage of steam required for atomizing the oil, however, also slightly increased as higher pressures were used.

During these tests deflectors were placed in the ash-pan openings, so as to cause the air to be drawn up near the burners, thus effecting combustion nearer the front of the furnace.

The average percentage of steam required for atomizing purposes as determined from the general range of these tests was about 4½ per cent. of the entire evaporation of the main or experimental boiler.

In these three tests the side burners were directed toward the center of the furnace more than heretofore in order to reduce the amount of heat absorbed by the side walls. The amount so absorbed was judged of by the condition of glow immediately after extinguishing the burners. This glow of the side walls, and also of the back and bridge walls, generally showed a more intense combustion on the right side of the furnace than on the left. The

fact that the steam and oil connections to the burners were also at the right side of the furnace front suggests the desirability of proportioning the piping, both as to size and location, so as to get substantially equal pressure at all burners.

Before making further tests the front wall of the furnace was rebuilt with ferruled openings, 8 inches in diameter, for the burners. Ample latitude was thus allowed for the angular setting of the burners, and there was also opportunity for trying the effect of admitting air around the burners.

An accident to the engine of the fan blower prevented the continuance of these trials with different pressures of forced draft. It should be ascertained just how much steam is required for atomizing purposes when the boiler is forced to its utmost.

The Board deems it important, when opportunity will permit, to make an extended series of tests with steam as the atomizing agent. Fresh water can be secured in unlimited quantities at nearly all naval stations, and it might not be a difficult matter to make arrangements whereby the torpedo boats and destroyers, when fitted with fuel oil-burning installations, could be furnished with an ample supply in specially constructed tanks, thus obviating the risk of being compelled to feed salt water into the boilers.

Even if compressed air should be used on the torpedo boats as the atomizing agent, an accident might happen to the compressor plant which would compel the temporary use of steam. There is therefore an urgent necessity to secure reliable data upon the subject of how much steam is required for spraying purposes under various conditions of natural and forced draft.

* * * *

TESTS OF CENTRIFUGAL BURNERS.

While experiments were being conducted with representative types of steam and air burners under the Hohenstein boiler, the possibility of using mechanical burners was given special consideration by the Board. Some independent experiments were projected with centrifugal burners, and it is a matter of regret that other important work devolving upon each member of the Board prevented extended consideration of this matter.

GENERAL PLAN

Test No.	Air or steam vaporizing.	Type of burner.	Draft.	Hours of run.	Date.	Oil used.
			inches			
1	Air	Oil City Boiler Works	1.2	6	1902. June 11	Texas.
2	do	do	2.25	4	June 12	do
3	do	do	Natural	8	June 26	do
4	do	do	3.2	3	June 27	do
5	do	do	Natural	5	Aug. 2	do
6	do	do	do	116	Aug. 4–9	do
7	do	do	0.10	6	Aug. 15	do
8	do	do	3.75	3	Aug. 20	do
9	Steam	Hayes	Natural	6	Sept. 12	do
10	do	Oil City Boiler Works	do	8	Sept. 19	do
11	do	do	do	8	Sept. 20	do
12	do	do	do	8	Sept. 22	do
13	Air and steam	Reed	do	8	Sept. 27	do
14	do	do	do	8	Sept. 29	do
15	Steam	Oil City Boiler Works—Hohenstein	do	8	Oct. 4	do
16	do	do	1	6	Oct. 13	do
17	do	do	2	4	Oct. 14	do
18	do	do	do	5	Oct. 22	do
19	do	do	3	2.5	Oct. 25	do
20	do	do	1	7	Oct. 27	do
21	do	"Advance"	Natural	7	Nov. 14	do
22	Air	do	do	8	Nov. 17	do
23	Steam	"Branch"	do	8	Nov. 28	do
24	do	do	2	4	Dec. 1	do
25	Air	do	do	2.75	Dec. 2	do
26	do	do	do	4	Dec. 4	do
27	Steam	do	do	5	Dec. 5	do
28	Air	do	do	1.9	Dec. 6	do
					1903.	
29	Steam	"Best"	do	4	Jan. 1	do
30	do	do	1	6	Jan. 3	do
31	do	do	3	4	Jan. 5	do
32	Air	Harvey system	Natural	8	Jan. 10	do
33	do	do	do	8	Jan. 12	do
34	do	"Best"	do	8	Jan. 15	do
35	do	do	1	6	Jan. 16	do

OF OIL TESTS.

Test No.	Air or steam vaporizing.	Type of burner.	Draft.	Hours of run.	Date.	Oil used.
			inches.		1903.	
36	Air	"Best"	2	5	Jan. 17	Texas.
37	do	do	3	3	Jan. 19	do
38	Steam	do	Natural	6	Jan. 20	do
39	do	"Advance"	do	7	Feb. 6	do
40	do	do	do	8	Feb. 9	do
41	do	"Advance" (improved)	do	8	Feb. 13	do
42	do	"Advance"	2	4	Feb. 27	do
43	do	do	1	6	Mar. 2	do
44	do	do	3	3	Mar. 3	do
45	do	Oil City Boiler Works—Hohenstein	do	4	Mar. 14	do
46	do	"Booth"—Santa Fe	Natural	8	Apr. 9	do
47	do	do	1	4	Apr. 10	do
48	do	do	Natural	6	Apr. 17	Calfor.
49	do	do	1	4	Apr. 18	do
50	do	do	3	3	Apr. 20	do
51	do	do	do	2+2	Apr. 21	do
52	do	do	do	2	Apr. 22	do
53	do	do	do	2	Apr. 23	do
54	do	do	do	3	Apr. 24	do
55	do	"MacDonald"	Natural	4	Apr. 27	do
56	do	"Oil City"—Hohenstein	do	4	May 4	do
57	do	do	do	6	May 5	do
58	do	do	1	5	May 6	do
59	do	do	2	4	May 7	do
60	do	do	3	3	May 8	do
61	do	Oil City "Fitton"	Natural	6	May 22	do
62	do	do	1	5	May 25	do
63	do	do	2	5	May 26	do
64	do	do	3	3	May 28	do
65	do	do	2	4	June 2	do
66	do	do	3	3	June 3	do
67	do	"Advance"	Natural	6	June 11	do
68		do	3	3	June 12	*
69	Air	Oil City "Fitton"	Natural	4	June 16	Mixt.

* Mixture, California and Texas.

SUMMARY OF OIL-BURNING TESTS WITH

No. of trial.	Date of trial.	Duration of trial (hours).	Kind of oil.	Oil burner used.	State of weather.
1	2	3	4	5	6
	1902.				
1	June 11	6		Oil City Works (air) ..	Bright, sunny day.....
2	June 12	4		do	do .....
3	June 26	8		do	do .....
4	June 27	3		do	Bright sun, few clouds....
5	Aug. 2	5		do	Bright, sunny day.....
6	Aug. 4–9	116		do	(See log) .....
7	Aug. 15	6		do	Thin, fleecy clouds .. ..
8	Aug. 20	3		do	Smoky; occasional clouds
9	Sept. 12	6		Hayes (steam).....	Partly cloudy .....
10	Sept. 19	8		Oil City Wrks. (steam)	Thin clouds.....
11	Sept. 20	8		do	do .....
12	Sept. 22	8		do	Partly cloudy. ....
13	Sept. 27	8		Reed (air and steam)..	Fair .....
14	Sept. 29	8		do	Clear .....
15	Oct. 4	8		Oil City (steam).....	Overcast, then drizzling..
16	Oct. 13	6	Beaumont oil.	do	Clear and pleasant ....
17	Oct. 14	4		do	Partly cloudy .....
18	Oct. 22	5		do	Clear .....
19	Oct. 25	2.5		do	do ....
20	Oct. 27	7		do	Drizzling and rain.....
21	Nov. 14	7		Advance Co. (steam)..	Misty .....
22	Nov. 17	8		Advance Co. (air).....	Misty and cloudy.....
23	Nov. 28	8		Branch (steam)	Cloudy.....
24	Dec. 1	4		do	Partly cloudy to clear .....
25	Dec. 2	2.75		Branch (air)	Clear and dry .....
26	Dec. 4	4		do	Heavy mist .....
27	Dec. 5	5		Branch (steam)	Wet and snowing.....
28	Dec. 6	1.92		Branch (air)	Heavy mist, then clearing.
29	Jan. 1, '03	4		Best (steam).....	Misty.....
30	Jan. 3	6		do	Overcast; heavy fog .....
31	Jan. 5	4		do	.....
32	Jan. 10	8		Harvey system (air)...	Clear, dry and cold.....
33	Jan. 12	8		do ...	Clear and cold.....
34	Jan. 15	8		Best (air).....	.....
35	Jan. 16	6		do	.....

[This boiler is shown opposite page 225, JOURNAL, Vol. XV, No. 1, February, 1903.]

HOHENSTEIN MARINE WATER-TUBE BOILER.

No. of trial.	Height of barometer at noon.	Degree of humidity.	Average pressure.										
			Steam pressure by gauge; corrected for water level (pounds per square inch).	Pressure of medium used for spraying oil (pounds per square inch).	Pressure on oil (pounds per square inch).	Draft pressure in inches of water.							
						Fireroom.	Furnace.	Combustion chamber.	Tube chamber.		Above tubes and below drums.	Base of stack.
									Front.	Back.		
1	7	7.1	8	9	9.1	10	11	12	13	13.1	13.2	14
1	30.02	...	273.5	3.20	...	1.27	0.78	0.642	0.25	...	...	—.49
2	30	...	273.5	4.62	...	2.31	1.55	1.38	.83	...	...	—.05
3	29.70	...	273.5	.78	...	0	—.15	—.19	—.25	...	...	—.35
4	29.94	...	273.5	3.37	...	3.25	2.60	2.02	1.25	...	...	—.41
5	30.13	...	273.5	1.41	...	0	—.15	—.20	—.28	...	...	—.40
6	29.89	...	271.5	1.31	...	0	—.17	—.23	—.30	...	...	—.46
7	30.10	...	272.5	4.66	...	0	—.09	—.13	—.21	...	...	—.54
8	30.08	...	276	4.68	...	3.75	3.40	2.30	1.86	...	...	—.53
9	30.16	...	273.5	32	...	0	—.20	—.20	—.20	...	...	—.38
10	30.20	...	273.1	29.9	...	0	—.20	—.20	—.28	...	...	—.60
11	30.18	...	273.7	61.4	...	0	—.14	—.20	—.28	...	...	—.53
12	30.05	...	274.2	91	...	0	—.14	—.16	—.21	...	...	—.53
13	29.92	...	276.7	92	...	0	—.15	—.15	—.20	...	...	—.45
14	29.96	...	277.4	89	...	0	—.097	—.10	—.20	...	...	—.50
15	29.99	...	276.6	91.8	45	0	—.14	—.15	—.25	...	...	—.50
16	29.85	59	275.1	92	45	1.03	1.03	.54	.26	...	...	—.50
17	29.93	66	273.2	90.2	45	2.04	1.69	1.28	.82	...	...	—.50
18	30.37	45	275.2	90	45	2.01	1.51	1.23	.65	...	...	—.52
19	30.14	58	273.2	91	32	3.02	2.61	2.23	1.25	...	...	—.41
20	29.96	86	274.3	91	31	1	.80	.57	.29	...	...	—.50
21	30.23	82	271.9	90	35	0	—.133	—.234	—.210	—.233	—.383	—.525
22	30.16	74	272.3	35	25	0	—.128	—.225	—.205	—.232	—.388	—.514
23	30.14	...	272	91.5	55	0	—.136	—.125	—.196	—.219	—.404	—.556
24	30.10	...	274	94.2	55	2	1.60	1	1.01	.90	—.22	—.532
25	29.96	...	264.6	49.1	30	2	1.60	1	1	1	—.30	—.422
26	30.04	...	274.6	49.2	36.5	2	1.60	1	1.05	.974	—.268	—.42
27	29.69	...	273.9	90.9	55	2	1.60	1	1	.97	—.26	—.43
28	30.36	...	273.4	49	35	2	1.60	1	1	.95	—.29	—.38
29	30.30	...	273.5	90	30	2	1.50	1	1	1	.20	—.40
30	29.63	...	273.2	90	30	1	.80	.47	.45	.45	—.05	—.50
31	29.85	...	273.2	90	33	3	2.40	1.60	1.60	1.50	.50	—.30
32	30.17	...	274.6	23	18	0	.17	.243	.226	.241	.411	.534
33	30.04	...	274.5	23	16	0	.147	.243	.223	.243	.38	.52
34	30.03	...	274.1	70	25	0	.138	.238	.217	.236	.393	.54
35	30.04	...	275.5	71	25	1	.80	.45	.43	.45	—.02	—.55

SUMMARY OF OIL-BURNING TESTS WITH

No. of trial.	Date of trial.	Duration of trial (hours).	Kind of oil.	Oil burner used.	State of weather.
1	2	3	4	5	6
	1903.				
36	Jan. 17	5	Beaumont oil.	Best (air)	
37	Jan. 19	3		do	Clear and cold.
38	Jan. 20	6		Best (steam)	
39	Feb. 6	7		Advance (steam)	Clear
40	Feb. 9	8		do	Clear cold; breeze NW.
41	Feb. 13	8		do	Clear
42	Feb. 27	4		do	Overcast; rain 2.30 to 5.
43	Mar. 2	6		do	Clear and cold.
44	Mar. 3	3		do	Clear
45	Mar. 14	4		Oil City Wrks. (steam)	Clear and pleasant
46	Apr. 9	8		Santa Fe (steam)	Clear and warm
47	Apr. 10	4		do	do
48	Apr. 17	6		do	Clear
49	Apr. 18	4		do	do
50	Apr. 20	3		do	Overcast
51	Apr. 21	4	California oil.	do	Clear
52	Apr. 22	2		do	do
53	Apr. 23	2		do	Partly cloudy
54	Apr. 24	3		do	Clear
55	Apr. 27	4		MacDonald (steam)	do
56	May 4	4		Oil City Wrks. (steam)	do
57	May 5	6		do	do
58	May 6	5		do	do
59	May 7	4		do	do
60	May 8	3		do	
61	May 22	6		do	Partly cloudy.
62	May 25	5		do	Overcast and misty.
63	May 26	5		do	Overcast and drizzling.
64	May 28	3		do	Partly cloudy
65	June 2	4		do	Clear
66	June 3	3		do	do
67	June 11	6		Advance (steam)	Overcast
68	June 12	3	*	do	Partly Cloudy.
69	June 16	4	*	Oil City (air)	Clear

* California and Texas oils.

HOHENSTEIN MARINE WATER-TUBE BOILER.—Continued.

No. of trial.	Height of barometer at noon.	Degree of humidity.	Average pressure.									
			Steam pressure by gauge; corrected for water level (pounds per square inch).	Pressure of medium used for spraying oil (pounds per square inch).	Pressure on oil (pounds per square inch).	Draft pressure in inches of water.						
						Fireroom.	Furnace.	Combustion chamber.	Tube chamber.		Above tubes and below drums.	Base of stack.
									Front.	Back.		
1	7	7.1	8	9	9.1	10	11	12	13	13.1	13.2	14
36	30.7	...	272.5	70	24	2	1.45	.95	.93	.95	.3	—.5
37	30.55	...	273.5	70	20	3	2.6	1.62	1.6	1.62	.6	—.6
38	30.38	...	272.5	90.5	20	0	.117	.28	.26	.28	.44	.614
39	30.29	...	273.5	60	60	0	.097	.224	.192	.221	.382	.526
40	30.15	...	273.5	30	40	0	.05	.205	.17	.203	.373	.542
41	30.03	...	273.5	20	27 6	0	.05	.197	.177	.21	.38	.53
42	30.26	...	272.5	20	25	2	1.7	1.2	1.2	1.14	.372	—.32
43	30.47	...	272.5	20	25	1	.8	.45	.42	.45	—.094	—.5
44	30.55	27	273.5	20	25	3	2.6	1.86	1.85	1.65	.61	—.42
45	30.2	32	273.5	90	60	3 7	2.92	.83	1.87	1.82	1.9	—.46
46	29.94	46	269.5	90	9	0	.2	.28	.265	.27	.35	.45
47	30.09	28	271.5	90	9	1	.6	.2	.28	.2	—.1	—.45
48	29.77	36	273.5	90	10.6	0	.16	.27	.25	.26	.35	.44
49	29.79	36	273.5	90	11	1	.65	.25	.2	.2	—.1	—.4
50	29.66	47	273.5	90	10	3	2.3	1.3	1.4	1.2	.5	—.45
51	29.7	25	267.5	90	23	3	2	1.2	1.3	1.1	.4	—.45
52	29.81	30	267.5	90	23	3	1.95	1	1.2	1	.45	—.35
53	29.9	29	262.5	90	25 4	3	1.95	1.12	1.2	1.1	.4	—.44
54	30.05	22	265.5	90	75	3	2.2	1.2	1.3	1.17	.48	—.45
55	30.2	32	263.5	90	40	0	.14	.27	.24	.27	.363	.45
56	30.2	41	265.5	90	40	0	.15	.27	.25	.27	.36	.46
57	30.19	36	265.5	90	41	0	.16	.27	.245	.27	.36	.46
58	30.16	24	267.5	90	45	1	.6	.25	.3	.25	—.05	—.4
59	30	25	267.5	90	52	2	.163	.86	1	.84	.24	—.44
60	30.17	30	267.5	90	71	3	2.5	1.4	1.5	1.4	.5	—.4
61	29.94	38	267.5	60	103	0	.7	.2	.19	.21	.31	—.43
62	30.25	47	268.5	60	128	1	.8	.3	.4	.3	—.1	—.5
63	30.33	47	270.5	60	139	2	.16	.9	1	.8	.2	—.5
64	30.09	50	272.5	60	142	3	2.5	1.4	1.5	1.43	.5	—.6
65	30.29	39	270.5	40	148	2	1.8	1.1	1.22	1.05	.32	—.48
66	30.23	39	267.5	90	131	3	2.53	1.4	1.5	1.3	.5	—.6
67	29.92	40	268.5	45	146	0	.06	.17	.16	.2	.35	.53
68	29.7	39	268.5	45	128	3	2.6	2	1.8	1.7	.7	—.5
69	29.83	36	267.5	43	136	0	.06	.15	.15	.18	.31	—.47

SUMMARY OF TEST OF HOHENSTEIN MARINE

No. of trial.	Approximate fireroom air pressure (inches of water).	Revolutions of fan blower per minute.	Draft openings into furnace (aggregate area in square inches).	Average temperatures (°F.).					
				Outside air.		Air in fireroom (5 feet above floor).	Oil in weighing tank.	Medium used in spraying oil.	Chimney gases.
				Dry bulb.	Wet bulb.				
1	10	15	15.1	16	16.1	17	17.2	18	19
1	1.3	327	...	85.4	...	121	...	(?)	704.6
2	2.3	423	...	86	...	121.5	...	(?)	779
3	0	0	...	79	...	106	...	102.5	503.6
4	3.3	483	...	81	...	108	...	122	854
5	0	0	...	87	...	112	...	120	557
6	0	0	...	79	...	112	...	113.5	585
7	0	0	...	77.6	...	120	...	161	747
8	3.75	506	...	82	...	115	...	136	1,017
9	0	0	...	75	...	98	...	(?)	449
10	0	0	...	69	...	98	...	444.4	596
11	0	0	...	77	...	106	...	408.2	628
12	0	0	...	77	...	103	...	401	661
13	0	0	...	80.4	...	99.4	...	375	578
14	0	0	...	85.4	...	111.5	...	416	645
15	0	0	500	64.4	...	91.2	65.8	407.4	635.6
16	1	303	692	76.3	67.3	114.6	68	482	701
17	2	392	830	68.2	61.6	104	65	545	849
18	2	380	554	61.3	49.8	97.6	58.6	534	842
19	3	463	800	77	67.7	112	65	469	1,050
20	1	287	800	68.1	65.6	108.7	65	420	818
21	0	0	569	58.2	55.3	78.3	54	321	640
22	0	0	369	57.2	53	81.5	56	243	642
23	0	0	476	...	...	72	46	370	699
24	2	382	476	...	...	82	42	378	796
25	2	392	476	...	...	82.7	46	326	778
26	2	384	680	...	...	80	46	333	740
27	2	369	660	Air at ash-pit opening.		72	40	379	816
28	2	370	672			70.4	31	310	733
29	2	383	776	86.4	72	71.5	36	427.4	750
30	1	283	776	108.8	81.1	83.6	32	407.1	687.5
31	3	448	776	101.8	78.6	77.5	40	443.5	790
32	0	0	776	113.4	85.9	86	30	341.9	565
33	0	0	752	90.2	76.8	58.6	25.4	294.4	540.2
34	0	0	...	...	...	73	37	288	...
35	1	285	...	...	...	87	36	340	...

WATER-TUBE BOILER, BURNING OIL.

No. of trial.	Average temperatures (°F.). Feed water entering boiler.	Average temperatures (°F.). Steam at gauge pressure from steam tables (8).	Oil. Weight of oil used during test (pounds).	Oil. Weight of steam used directly or indirectly in spraying oil, in latter case assuming 34# evaporative units per hour per I.H.P.	Steam. Quality.	Steam. Percentage of moisture in steam, 100 − (24).	Water. Total weight of water fed to boiler, pounds (corrected for inequality of water level and steam pressure at beginning and end of tests).	Water. Equivalent weight of water evaporated into dry steam (pounds), (26) × (24).	Water. Factor of evaporation $H-h+965.7$.	Water. Equivalent weight of water evaporated into dry steam from and at 212° F. (pounds), (27) × (28).
1	20	21	22	23	24	25	26	27	28	29
1	120.7	413.7	10,580	2,820	0.983	1.7	117,976	115,960	1.159	134,400
2	103.2	413.7	9,180	3,770	.980	2	96,928	94,980	1.177	111,800
3	128.5	413.7	6,122	827	.984	1.6	78,000	76,740	1.151	88,330
4	119	413.7	8,602	2,550	.981	1.9	88,604	86,915	1.161	100,900
5	129	413.7	4,668	1,153	.986	1.4	58,529	57,700	1.151	66,380
6	119.4	413.1	96,517	18,240	.985	1.5	1,192,482	1,174,500	1.160	1,363 000
7	119.7	413.4	9,089	7,800	.995	.5	104,631	104,100	1.160	120,780
8	119	414.5	9,909	3,950	.988	1.2	92,997	91,870	1.161	106,690
9	127	413.7	3,600	2,524	.991	.9	43,761	43,367	1.153	50,000
10	118.3	413.6	7,360	3,412	.995	.5	85,791	85,350	1.162	99,170
11	120.2	413.8	8,257	4,252	.994	.6	96,469	95,880	1.160	111,190
12	119.6	414	8,974	5,305	.995	.5	105,547	105,020	1.160	121,840
13	121.9	414.8	7,692	8,166	.996	.4	95,605	95,310	1.158	110,370
14	120.8	415	9,216	6,838	.998	.2	112,115	111,890	1.159	129,570
15	119.9	414.7	8,071	4,831	.985	1.5	91,869	90,491	1.160	104,970
16	119.3	414.3	9,379	2,204	.971	2.9	95,283	92,520	1.161	107,410
17	119.1	413.6	9,220	1,445	.982	1.8	82,414	80,931	1.161	93,961
18	119.9	414.3	10,535	3,126	.982	1.8	104,785	102,899	1.159	119,260
19	109.2	413.6	7,445	2,654	.982	1.8	68,246	67,018	1.171	78,478
20	118.7	414	13,781	8,646	.984	1.6	149,160	146,773	1.161	170,403
21	119.9	413.1	7,517	7,237	.981	1.9	85,069	83,453	1.160	108,405
22	119.5	413.4	8,676	9,524	.984	1.6	100,300	98,695	1.161	114,486
23	119.8	413.3	10,117	9,885	.985	1.5	116,120	114,378	1.160	132,678
24	110.2	414	7,995	4,341	.981	1.9	80,128	78,605	1.170	91,968
25	110.6	411	5,383	3,416	.981	1.9	54,326	53,294	1.169	62,301
26	109.2	414.2	7,240	3,312	.979	2.1	70,765	69,278	1.171	81,124
27	102.1	413.9	10,475	5,939	.979	2.1	103,501	101,327	1.179	119,464
28	102.4	413.8	3,697	2,163	.977	2.3	37,804	36,935	1.178	43,509
29	94.6	413.8	8,159	2,672	.976	2.4	81,697	79,736	1.187	94,647
30	106.3	413.7	10,163	4,787	.976	2.4	109,310	106,686	1.174	125,249
31	97.4	413.7	9,940	3,299	.974	2.6	102,242	99,584	1.183	117,808
32	118.1	414.2	7,636	3,174	.984	1.6	92,890	91,403	1.162	106,210
33	118	414.2	7,362	3,588	.983	1.7	90,803	89,259	1.162	103,719
34	118.6	414	9,068	9,524	.9837	1.63	106,839	105,097	1.161	122,017
35	107	414.4	10,280	7,659	.9765	2.35	110,952	108,344	1.174	127,196

SUMMARY OF TEST OF HOHENSTEIN MARINE

No. of trial.	Approximate fireroom air pressure (inches of water).	Revolutions of fan blower per minute.	Draft openings into furnace (aggregate area in square inches).	Average temperatures (°F.).					
				Outside air.		Air in fireroom (5 feet above floor).	Oil in weighing tank.	Medium used in spraying oil.	Chimney gases.
				Dry bulb.	Wet bulb.				
1	10	15	15.1	16	16.1	17	17.2	18	19
36	2	375	...	...	...	80	36	358	...
37	3	445	...	72	62	59	28	366	717
38	0	0	...	...	...	63	29	358	...
39	0	0	...	130	98	83	37·5	384	610
40	0	0	...	125	95.6	84	37	396	662
41	0	0	...	153	110	104	...	401	644
42	2	385	...	...	...	90	...	400	714
43	1	280	...	120	95	85	...	376	698
44	3	458	...	77	57	89	...	423	775
45	3·7	501	...	94	71	104	...	447	819
46	0	0	...	78	64	88	...	334	462
47	1	280	...	88	65	102	...	375	578
48	0	0	...	81	63	84	110	334	487
49	1	280	...	84	65	98	...	352	535
50	3	464	...	84	69	96	...	378	743
51	3	460	...	83	61	92	...	364	722
52	3	457	...	78	59	87	...	362	767
53	3	456	...	76	57	86	...	356	788
54	3	457	...	86	62	96	...	374	867
55	0	0	...	90	67.6	93	160	325	571
56	0	0	...	84	67	88	160	332	579
57	0	0	...	87	68	88	160	340	600
58	1	287	...	97	70	108	160	375	792
59	2	387	...	101	73	111	160	396	930
60	3	458	...	92	69	112	160	411	1,053
61	0	0	...	108	83	116	160	343	598
62	1	287	...	86	71	102	160	375	746
63	2	386	...	87	72	101	160	384	791
64	3	474	...	102	85	...	160	400	827
65	2	409	...	96	76	...	160	387	727
66	3	460	...	100	79	...	120	436	895
67	0	0	...	110	87	90	140	...	774
68	3	472	...	95	75	110	130	483	943
69	0	0	...	108	83	111	150	341	675

WATER-TUBE BOILER, BURNING OIL.—Continued.

No. of trial.	Average temperatures (°F.).		Oil.		Steam.		Water.			
	Feed water entering boiler.	Steam at gauge pressure from steam tables (8).	Weight of oil used during test (pounds).	Weight of steam used directly or indirectly in spraying oil, in latter case assuming 34f evaporative units per hour per I.H.P.	Quality.	Percentage of moisture in steam, 100 − 100 × (24).	Total weight of water fed to boiler, pounds (corrected for inequality of water level and steam pressure at beginning and end of tests).	Equivalent weight of water evaporated into dry steam (pounds), (26) × (24).	Factor of evaporation $H-h \div 965.7$.	Equivalent weight of water evaporated into dry steam from and at 212° F. (pounds), (27) × (28).
1	20	21	22	23	24	25	26	27	28	29
36	102	413.5	9,824	6,727	.9757	2.43	101,917	99,440	1.178	117,140
37	97	413.8	6,950	3,726	.9749	2.51	67,620	65,923	1.184	78,053
38	120	413.5	7,216	3,744	.9818	1.82	86,061	84,495	1.159	97,930
39	119	413.8	6,829	3,936	.985	1.50	74,692	73,572	1.161	85,417
40	120	413.8	9,578	4,207	.9858	1.42	108,212	106,675	1.16	123,743
41	120	413.8	8,741	3,098	.9859	1.41	98,343	96,956	1.16	112,468
42	119	413.5	6,578	1,680	.9756	2.44	61,374	59,876	1.161	69,516
43	120	413.5	8,385	2,683	.9775	2.25	82,486	80,630	1.16	93,530
44	119	413.8	6,005	1,299	.9761	2.39	54,872	53,560	1.161	62,183
45	108	413.8	10,460	3,239	.9762	2.38	108,257	105,680	1.172	123,857
46	119	412.6	5,758	6,793	.9831	1.69	67,548	66,406	1.161	77,097
47	120	413.2	5,245	3,148	.9836	1.64	58,942	57,975	1.16	67,251
48	120	413.8	4,571	5,358	.9807	1.93	51,746	50,747	1.16	58,866
49	119	413.8	5,213	4,016	.9829	1.71	55,281	54,336	1.161	63,084
50	117	413.8	6,021	3,878	.9813	1.87	59,009	57,905	1.163	67,343
51	121	412.2	5,802	3,197	.9808	1.92	52,535	51,526	1.158	59,667
52	120	412.2	2,756	1,619	.9797	2.03	24,623	24,123	1.159	27,958
53	120	410.3	2,645	1,381	.9812	1.88	22,132	21,716	1.159	25,169
54	120	411.3	4,747	2,702	.9803	1.97	40,190	39,398	1.159	45.662
55	120	410.6	3,445	4,240	.985	1.5	39,236	38,649	1.159	44.794
56	119	411.3	3,280	2,926	.9834	1.66	36,595	35,987	1.16	41,745
57	120	411.3	5,131	4,737	.983	1.7	58,259	57,268	1.159	66,374
58	120	411.9	7,114	3,801	.9817	1.83	75,603	74,219	1.159	86,030
59	119	411.9	7,172	3,685	.9814	1.86	74,975	73,580	1.16	85,353
60	116	411.9	7,359	2,869	.9796	2.04	71,905	70,438	1.163	81,919
61	120	411.9	5,898	4,833	.9824	1.76	68,693	67,484	1.159	78,214
62	120	412.2	8,135	4,319	.9789	2.11	84,767	82,978	1.159	96,171
63	119	412.9	9,844	3,841	.9778	2.22	97,687	95,518	1.161	110,896
64	119	413.5	7,172	2,909	.977	2.3	71,261	69,621	1.161	80,830
65	120	412.9	7,747	2,140	.9795	2.05	76,621	75,050	1.16	87,058
66	120	411.9	7,818	4,175	.9802	1.98	77,158	75,630	1.159	87,655
67	121	412.2	6,922	3,085	.9806	1.95	72,298	70,895	1.158	82,096
68	120	412.2	7,945	1,995	.977	2.3	72,777	71,103	1.159	82,408
69	121	411.9	4,438	3,395	.9796	2.04	49,530	48,519	1.158	56,185

SUMMARY OF TEST OF HOHENSTEIN MARINE

No. of trial.	Approximate fireroom air pressure (inches of water).	Economic results.					Oil fuel per hour.			
		Feed water per pound of oil (pounds), (20) ÷ (22).	Equivalent evaporation from and at 212° F. per pound of oil (pounds), (29) ÷ (22).	Pounds of steam used in spraying oil per pound of oil, (23) ÷ (22).	Steam used in spraying oil (per cent. of total steam generated), (23) ÷ (26) × 100.	Cubic feet of free air used in spraying oil per pound of oil sprayed.	Oil per hour (pounds), (22) ÷ (3).	Oil per hour per horizontal square foot of furnace (pounds), (35) ÷ 50.14.	Oil per hour per square foot of heating surface (pounds), (35) ÷ 2130.	Steam consumed in spraying oil (pounds per hour), (23) ÷ (3).
1	10	30	31	32	33	34	35	36	37	38
1	1.3	11.15	12.7	0.303	2.39	34.3	1,764	35.15	0.83	535
2	2.3	10.56	12.18	.474	3.89	37.4	2,295	45.8	1.08	1,088
3	0	12.74	14.43	.153	1.06	62.8	765	15.25	.36	117.5
4	3.3	10.3	11.73	.337	2.88	36.7	2,867	57.2	1.35	967
5	0	12.54	14.22	.28	1.97	70	933.6	18.6	.44	262
6	0	12.36	14.12	.216	1.53	55.4	832	16.6	.39	179.5
7	0	11.52	13 29	.99	7.45	78.3	1,515	30.2	.71	1,501
8	3.75	9.39	10.77	.458	4.25	36	3,303	65.9	1.55	1,511
9	0	12.16	13.89	.701	5.77	0	600	11.97	.28	421
10	0	11.65	13.47	.464	3.98	0	920	18.34	.43	427
11	0	11.68	13.45	.515	4.41	0	1,032	20.57	.48	532
12	0	11.77	13.58	.591	5.03	0	1,122	22.35	.53	663
13	0	12.43	14.35	1.062	8.54	81.4	962	19.15	.45	1,021
14	0	12.17	14.06	.742	6.09	78	1,152	22.95	.54	855
15	0	11.38	13	.599	5.26	0	1,009	20.12	.4738	603.9
16	1	10.16	11.45	.235	2.31	0	1,563	31.17	.7338	367.4
17	2	8.94	10.19	.157	1.75	0	2,305	45.97	1.0823	361.2
18	2	9.95	11.32	.297	2.98	0	2,107	42.02	.9893	625.2
19	3	9.17	10.54	.356	3.89	0	2,978	59.39	1.3983	1,062
20	1	10.82	12.37	.627	5.8	0	1,969	39.27	.9244	1,235.1
21	0	12.65	14.42	.963	8.51	0	1,074	21.42	.5042	1,034
22	0	11.57	13.19	1.098	9.49	16.12	1,085	21.64	.5094	1,190.5
23	0	11.48	13.11	.977	8.51	0	1,265	25.23	.594	1,235.6
24	2	10.022	11.5	.543	5.42	0	1,999	39.86	.9387	1,085.2
25	2	10.093	11.57	.634	6.29	7.94	1,794	35.78	.8422	1,242.3
26	2	9.774	11.2	.457	4 68	5.7	1,810	36.1	.8499	828
27	2	9.881	11.4	.567	5.74	0	2,095	41.78	.9838	1,187.8
28	2	10.227	11.77	.585	5.72	7.57	1,929	38.47	.9057	1,126.7
29	2	10.012	11.6	.327	3.27	0	2,040	40.68	.9578	668
30	1	10.758	12.33	.471	4.38	0	1,694	33.78	.7952	797.8
31	3	10.285	11.85	.332	3.23	0	2,485	49.56	1.1669	825
32	0	12.164	13.91	.416	3.42	5.49	954	19.03	.448	396.7
33	0	12.335	14.09	.487	3.95	7.18	920	18.35	.432	448.5
34	0	11.783	13.46	1.05	8.92	11.48	1,136	22.66	.5334	1,190.5
35	1	10.794	12.37	.745	6.9	7.96	1,713	34.17	.8042	1,276.5

WATER-TUBE BOILER, BURNING OIL.

No. of trial.	Water per hour.					Chimney gas analysis.			
	Feed water per hour (pounds), (26) ÷ (3).	Water per hour corrected for quality of steam (pounds), (27) ÷ (3).	Equivalent evaporation from and at 212° F. per hour (pounds), (29) ÷ (3).	Equivalent evaporation from and at 212° F. per hour per horizontal square foot of furnace (pounds), (41) ÷ 50.14.	Equivalent evaporation from and at 212° F. per hour per square foot of heating surface (pounds), (41) ÷ 2130.	Carbonic acid, CO_2 (per cent.).	Oxygen, O (per cent.).	Carbonic oxide, CO (per cent.).	Nitrogen, N (per cent. by difference).
1	39	40	41	42	43	44	45	46	47
1	19,663	19,327	22,400	447	10.5	6.97	8.77	1.5	82.76
2	24,232	23,745	27,975	558	13.1	6.96	9.2	1.2	82.64
3	9,750	9,593	11,041	220	5.18	7.24	10.2	.425	82.135
4	29,535	28,972	33,633	671	15.8	7.5	10.4	.3	81.8
5	11,706	11,540	13,276	265	6.23	7.7	10	.13	82.17
6	10,280	10,125	11,750	234	5.52	7.68	10.25	.06	82.01
7	17,447	17,360	20,137	402	9.45	10.1	6.64	.275	82.985
8	31,001	30,629	35,560	709	16.7	7.87	9.66	.22	82.25
9	7,294	7,228	8,333	166	3.91	5.5	13.05	.27	81.18
10	10,724	10,669	12,396	247	5.82	6.99	11.05	.013	81.95
11	12,057	11,985	13,899	277	6.52	7 47	10.66	.086	81.78
12	13,193	13,128	15,230	303	7.15	8.44	9.29	.014	82.26
13	11,951	11,914	13,796	275	6.48	7.7	9.85	.075	82.37
14	14,014	13,986	16,196	323	7.6	8.53	9.04	.05	82.38
15	11,484	11,311	13,121	261.7	6.16	8.03	9.6	.33	82.04
16	15,881	15,420	17,903	357.1	8.4	6.57	11.43	.18	81.82
17	20,604	20,233	23,490	468.5	11.03	7.3	10.73	.43	81.54
18	20,957	20,580	23,852	475.7	11.2	6.98	9.96	.12	82.99
19	27,298	26,807	31,391	626.1	14.74	8.6	10.4	.8	80.2
20	21,309	20,968	24,343	485.5	11.43	8.73	8.73	.1	82.44
21	12,153	11,922	15,486	308.8	7.27	7.86	9.27	.035	82.83
22	12,538	12,337	14,311	285.4	6.72	...	...	...	...
23	14,515	14,297	16,584	330.8	7.79	8.3	11.1	.5	80.1
24	20,032	19,651	22,992	458.5	10.79	6	11.3	.8	81.9
25	19,755	19,380	22,655	451.8	10.63	5.7	11.9	.8	81.6
26	17,691	17,320	20,281	404.5	9.52	...	...	...	...
27	20,700	20,265	23,893	476.5	11.22	...	...	...	...
28	19,690	19,237	22,661	452	10.64	...	...	...	...
29	20,424	19,934	23,662	471.9	11.11	6.9	11.9	.33	80.87
30	18,218	17,781	20,875	416.3	9.80	7.8	10.5	.07	81.63
31	25,561	24,896	29,452	587.3	13.83	7.3	10	.7	82
32	11,611	11,425	13,276	264 8	6.23	6.5	12.2	.02	81.28
33	11,350	11,157	12,965	258.6	6.09	6.3	12.2	.1	81.4
34	13,355	13,137	15,252	304.2	7.16	...	...	...	...
35	18,492	18,057	21,199	422.8	9.95	...	...	...	...

SUMMARY OF TEST OF HOHENSTEIN MARINE

No. of trial.	Approximate fireroom air pressure (inches of water).	Economic results.					Oil fuel per hour.			
		Feed water per pound of oil (pounds), (26) ÷ (22).	Equivalent evaporation from and at 212° F. per pound of oil (pounds), (29) ÷ (22).	Pounds of steam used in spraying oil per pound of oil, (23) ÷ (22).	Steam used in spraying oil (per cent. of total steam generated), (23) ÷ (26) × 100.	Cubic feet of free air used in spraying oil per pound of oil sprayed.	Oil per hour (pounds), (22) ÷ (3).	Oil per hour per horizontal square foot of furnace (pounds), (35) ÷ 30.14.	Oil per hour per square foot of heating surface (pounds), (35) ÷ 2130.	Steam consumed in spraying oil (pounds per hour), (23) ÷ (3).
1	10	30	31	32	33	34	35	36	37	38
36	2	10.375	11.92	.685	6.6	7.32	1,965	39.19	.9226	1,345.4
37	3	9.729	11.23	.536	5.51	5.75	2,317	46.21	1.0878	1,242
38	0	11.925	13.57	.519	4.35	0	1,219	24.31	.5723	624
39	0	10.943	12.51	.576	5.27	0	976	19.47	.4582	562
40	0	11.298	12.92	.439	3.88	0	1,197	23.88	.562	526
41	0	11.252	12.87	.354	3.15	0	1,093	21.8	.5132	387
42	2	9.33	10.57	.255	2.74	0	1,645	32.81	.7724	420
43	1	9.838	11.16	.32	3.25	0	1,398	27.88	.6564	447
44	3	9.138	10.36	.216	2.37	0	2,002	39.93	.94	433
45	3.7	10.35	11.84	.31	2.99	0	2,615	52.16	1.228	810
46	0	11.731	13.39	1.18	10.06	0	720	14.36	.3381	849
47	1	11.238	12.82	.6	5.34	0	1,311	26.15	.6155	787
48	0	11.321	12.88	1.172	10.36	0	762	15.2	.3578	893
49	.1	10.606	12.1	.77	7 26	0	1,303	25.99	.6118	1,004
50	3	9.8	11.19	.644	6.57	0	2,007	40.03	.9424	1,293
51	3	9.055	10.29	.551	6.08	0	1,450	28.92	.6808	799
52	3	8.935	10.14	.587	6.57	0	1,378	27.47	.6471	809
53	3	8.367	9.52	.522	6.24	0	1,323	26.38	.6212	690
54	3	8.467	9.62	.569	6.72	0	1,582	31.55	.7429	901
55	0	11.389	13	1.231	10.81	0	861	17.17	.4043	1,060
56	0	11.158	12.73	.892	7.99	0	820	16.35	.385	731
57	0	11.355	12.94	.923	8.13	0	855	17.05	.4014	790
58	1	10.629	12.09	.534	5.03	0	1,423	28.38	.668	760
59	2	10.453	11.9	.514	4.19	0	1,793	35.76	.8418	921
60	3	9.772	11.13	.39	3.99	0	2,453	48.93	1.1516	956
61	0	11.648	13.26	.82	7.04	0	983	19.61	.4615	805
62	1	10.422	11.82	.531	5.09	0	1,627	32.45	.7638	864
63	2	9.924	11.27	.39	3.93	0	1,969	39.27	.9244	768
64	3	9.936	11.27	.406	4.08	0	2,391	47.68	1.1228	969
65	2	9.892	11.24	.276	2.79	0	1,937	38.63	.9094	535
66	3	9.87	11.21	.534	5.41	0	2,606	51.97	1.2237	1,392
67	0	10.444	11.86	.446	4.27	0	1,154	23.01	.5418	514
68	3	9.159	10.37	.251	2.74	0	2,648	52.81	1.2433	665
69	0	11.162	12.66	.765	6.86	11.55	1,109	22.12	.5207	849

WATER-TUBE BOILER, BURNING OIL.—Continued.

No. of trial.	Water per hour.					Chimney gas analysis.			
	Feed water per hour (pounds), (26) ÷ (3).	Water per hour corrected for quality of steam (pounds), (27) ÷ (3).	Equivalent evaporation from and at 212° F. per hour (pounds), (29) ÷ (3).	Equivalent evaporation from and at 212° F. per hour per horizontal square foot of furnace (pounds), (41) ÷ 30.14.	Equivalent evaporation from and at 212° F. per hour per square foot of heating surface (pounds), (41) ÷ 2130.	Carbonic acid, CO_2 (per cent.).	Oxygen, O (per cent.).	Carbonic oxide, CO (per cent.).	Nitrogen, N (per cent. by difference).
1	39	40	41	42	43	44	45	46	47
36	20,384	19,888	23,428	467.3	11	...	...	...	...
37	22,540	21,974	26,018	518.9	12.22	6.7	12.3	.1	80.9
38	14,343	14,083	16,322	325.5	7.66	...	...	...	...
39	10,670	10,510	12,202	243.3	5.73	7.4	10.6	.1	81.9
40	13,527	13,334	15,468	308.5	7.26	7.85	10.4	.075	81.675
41	12,293	12,119	14,059	280.3	6.6	7.3	11.1	.2	81.4
42	15,344	14,969	17,379	346.6	8.16	...	...	...	...
43	13,748	13,438	15,588	310.9	7.32	4.8	13.2	.6	81.4
44	18,291	17,853	20,728	413.4	9.73	7	11	.4	81.6
45	27,064	26,420	30,964	617.5	14.54	5	14	.2	80.8
46	8,444	8,301	9,637	192.2	4.53	7.1	12	0	80.9
47	14,735	14,494	16,813	335.3	7.89	6.7	12.4	.1	80.8
48	8,624	8,458	9,811	195.7	4.61	7.7	14.2	2.1	76
49	13,820	13,584	15,771	314.6	7.4	8.6	11	1.1	79.3
50	19,670	19,302	22,448	447.7	10.54	6.6	12.6	.4	80.4
51	13,134	12,882	14,917	297.5	7	4.6	14.3	.2	80.9
52	12,312	12,062	13,979	278.8	6.56	5	14	0	81
53	11,066	10,858	12,585	251	5.91	4.8	14.4	0	80.8
54	13,397	13,133	15,221	303.5	7.15	4.8	13.4	.6	81.2
55	9,809	9,662	11,199	223.3	5.26	6	12.8	0	81.2
56	9,149	8,997	10,436	208.1	4.9	6	12.8	0	81.2
57	9,710	9,545	11,062	220.6	5.19	6.7	10.9	.2	82.2
58	15,121	14,844	17,206	343.2	8.08	7.2	11.4	.3	81.1
59	18,744	18,395	21,338	425.6	10.02	5.8	12.6	.2	81.4
60	23,968	23,479	27,306	544.6	12.82	7.2	11.6	.4	80.8
61	11,449	11,247	13,036	260	6.12	6.6	12	0	81.4
62	16,953	16,596	19,234	383.6	9.03	6.4	12.5	.2	80.9
63	19,537	19,104	22,179	442.3	10.41	6.4	12	.1	81.5
64	23,754	23,207	26,943	537.4	12.65	8.6	10.8	.2	80.4
65	19,155	18,763	21,765	434.1	10.22	6	12	0	82
66	25,719	25,210	29,218	582.7	13.72	8.6	10.2	.6	80.6
67	12,050	11,816	13,683	272.9	6.42	8.2	10	.2	81.6
68	24,259	23,701	27,469	547.8	12.90	7	12	0	81
69	12,382	12,130	14,046	280.1	6.59	7.8	10.4	0	81.8

SUMMARY OF TEST OF HOHENSTEIN MARINE

No. of trial.	Approximate fireroom air pressure (inches of water).	Pounds of dry chimney gas per pound of carbon. [11 (44) + 8 (45) + 7 (46) + 3 (44) + 3 (46)].	Percentage of carbon in oil by chemical analysis.	Pounds of dry chimney gas per pound of oil, (48) × (49).	Heat balance, or distribution of the heating value of the oil. In British thermal units.				
					Heat absorbed by the boiler, (31) × 965.7.	Loss due to superheated steam used in spraying oil.	Loss due to moisture formed by the burning of hydrogen.	Loss due to heat carried away in dry chimney gases.	Loss due to incomplete combustion of carbon.
1	10	48	49	50	51	52	53	54	55
1	1.3	28.99	83.26	24.1	12,250	0	1,440	3,375	1,495
2	2.3	30.11	83.26	25.1	11,760	0	1,480	3,925	1,242
3	0	32.15	83.26	26.8	13,930	0	1,350	2,565	469
4	3.3	31.64	83.26	26.4	11,320	0	1,540	4,720	326
5	0	31.54	83.26	26.3	13,720	0	1,370	2,800	141
6	0	31.91	83.26	26.6	13,620	0	1,390	3,020	66
7	0	24	83.26	20	12,830	0	1,470	2,945	224
8	3.75	30.54	83.26	25.4	10,400	0	1,620	5,480	230
9	0	42.47	83.26	35.4	13,413	58	1,366	2,990	395
10	0	35.16	83.26	29.3	13,008	77	1,445	3,500	16
11	0	32.64	83.26	27.2	12,989	79	1,458	3,410	97
12	0	29.29	83.26	24.4	13,114	93	1,479	3,270	14
13	0	31.7	83.26	26 4	13,857	125	1,431	3,000	82
14	0	28.85	83.26	24	13,578	112	1,465	3,070	49
15	0	29.57	83.26	24.62	12,551	87.2	1,469	3,217	333.6
16	1	36.43	83.26	30.33	11,056	41.6	1,502	4,269	225.3
17	2	31.9	83.26	26.56	9,840	39	1,585	4,745	470
18	2	34.66	83.26	28.86	10,930	72.8	1,588	5,150	142.8
19	3	26.41	83.26	21.99	10,177	122.7	1,692	4,952	719.2
20	1	28.16	83.26	23.44	11,944	146.4	1,568	3,992	957.5
21	0	31.29	83.26	26.05	13,923	142.8	1,485	3,510	37.4
22	0	...	83.26	...	12,736	...	1,484	...	...
23	0	28.19	83.26	23.47	12,657	172.1	1,525	3,530	480.2
24	2	36.04	83.26	30.01	11,105	120.5	1,581	5,140	994.2
25	2	37.68	83.26	31.37	11,172	...	1,567	5,210	1,040
26	2	...	83.26	...	10,815	...	1,547	...	...
27	2	...	83.26	...	11,006	131.9	1,595	...	...
28	2	...	83.26	...	11,363	...	1,560	...	...
29	2	34.1	83.26	28.39	11,202	65.8	1,564	4,619	385.7
30	1	31.41	83.26	26.15	11,904	80.6	1,535	3,786	75.1
31	3	30.8	83.26	25.64	11,440	73.1	1,581	4,381	739.4
32	0	37.74	83.26	31.42	13,433	...	1,471	3,581	25.9
33	0	38.4	83.26	31.97	13,605	...	1,463	3,672	132
34	0	...	83.26	...	12,994	...	...	...	...
35	1	...	83.26	...	11,947	...	...	...	...

WATER-TUBE BOILER, BURNING OIL.

No. of trial.	Heat balance or distribution of the heating value of the oil.								Efficiency.	
	In British thermal units.		In percentages of the total heating value of the oil.							
	Other losses—due to unconsumed hydrogen, to heating moisture in air, to radiation, etc., by difference.	Heat value of one pound of oil, calculated from chemical analysis.	Heat absorbed by boiler.	Loss due to superheating steam used in spraying oil.	Loss due to moisture formed by the burning of hydrogen.	Loss due to heat carried away in dry chimney gases.	Loss due to incomplete combustion of carbon.	Other losses—due to unconsumed hydrogen, to heating moisture in air, to radiation, etc., by difference.	Of boiler (per cent.), $(61) \div (57) \times 100 = (58)$.	Of boiler and furnace (per cent.), $(64) \times \left[1 - \frac{(33)}{100}\right]$.
1	56	57	58	59	60	61	62	63	64	65
1	921	19,481	62.8	0	7.4	17.3	7.7	4.8	62.8	61.3
2	1,074	19,481	60.3	0	7.6	20.1	6.4	5.6	60.3	58
3	1,167	19,481	71.5	0	6.9	13.2	2.4	6	71.5	70.7
4	1,575	19,481	58.1	0	7.9	24.2	1.7	8.1	58.1	56.4
5	1,450	19,481	70.4	0	7	14.4	.7	7.5	70.4	69
6	1,385	19,481	69.9	0	7.1	15.5	.3	7.2	69.9	68.8
7	2,012	19,481	65.8	0	7.5	15.1	1.2	10.4	65.8	60.9
8	1,751	19,481	53.4	0	8.3	28.1	1.2	9	53.4	51.1
9	1,259	19,481	68.9	.3	6.9	15.4	2	6.5	68.9	64.9
10	1,435	19,481	66.7	.4	7.4	18	.1	7.4	66.7	64.1
11	1,448	19,481	66.7	.4	7.5	17.5	.5	7.4	66.7	63.8
12	1,511	19,481	67.3	.5	7.6	16.8	.1	7.7	67.3	63.9
13	986	19,481	71.1	.6	7.4	15.4	.4	5.1	71.1	65
14	1,207	19,481	69.7	.6	7.5	15.7	.3	6.2	69.7	65.4
15	1,822	19,481	64.43	.448	7.54	16.51	1.713	9.352	64.43	61.04
16	2,387	19,481	56.74	.214	7.71	21.91	1.156	12.255	56.74	55.42
17	2,802	19,481	50.51	.2	8.14	24.36	2.413	14.383	50.51	49.62
18	1,597	19,481	56.11	.374	8.15	26.44	.733	8.199	56.11	54.43
19	1,818	19,481	52.2	.63	8.69	25.42	3.692	9.333	52.2	50.59
20	873	19,481	61.31	.752	8.05	20.49	4.916	4.482	61.31	57.74
21	383	19,481	71.47	.733	7.62	18.02	.192	1.966	71.47	65.39
22	...	19,481	65.37	...	7.62	...	...	...	65.37	59.16
23	1,117	19,481	64.98	.883	7.83	18.12	2.465	5.733	64.98	59.45
24	540	19,481	57.01	.616	8.12	26.38	5.104	2.772	57.01	53.91
25	492	19,481	57.34	...	8.04	26.75	5.338	2.525	57.34	53.73
26	...	19,481	55.51	...	7.94	...	...	...	55.51	52.91
27	6,748	19,481	56.5	.677	8.19	...	...	34.635	56.5	53.25
28	...	19,481	58.33	...	8.01	...	...	...	58.33	54.98
29	1,644	19,481	57.5	.338	8.03	23.71	1.98	8.438	57.5	55.61
30	2,111	19,481	61.11	.414	7.88	19.44	.38	10.836	61.11	58.45
31	1,266	19,481	58.73	.375	8.12	22.49	3.795	6.5	58.73	56.83
32	970	19,481	68.96	...	7.55	18.38	.133	4.979	68.96	66.61
33	609	19,481	69.83	...	7.51	18.85	6.777	3.126	69.83	67.07
34	...	19,481	66.7	...	...	...	...	...	66.7	60.75
35	...	19,481	61.33	...	...	...	...	...	61.33	57.09

SUMMARY OF TEST OF HOHENSTEIN MARINE

No. of trial.	Approximate firerom air pressure (inches of water).	Pounds of dry chimney gas per pound of carbon. [11 (44) + + 8 (45) + 7 (46) + 7 (47)] [3 (44) + 3 (46)].	Percentage of carbon in oil by chemical analysis.	Pounds of dry chimney gas per pound of oil, (48) × (49).	Heat balance, or distribution of the heating value of the oil. In British thermal units.				
					Heat absorbed by the boiler, (31) × 965.7.	Loss due to superheated steam used in spraying oil.	Loss due to moisture formed by the burning of hydrogen.	Loss due to heat carried away in dry chimney gases.	Loss due to incomplete combustion of carbon.
1	10	48	49	50	51	52	53	54	55
36	2	...	83.26	...	11,514	...	...	...	...
37	3	36.23	83.26	30.16	10,844	...	1,555	4.777.2	124.2
38	0	...	83.26	...	13,104	...	...	...	...
39	0	32.9	83.26	27.39	12,078	83.75	1,487.1	3,463.8	112.6
40	0	31.2	83.26	25.98	12,476	81.77	1,515.4	3,603 5	79.9
41	0	32.9	83.26	27.39	12,423	65.48	1,464.5	3,549.5	225.4
42	2	...	83.26	...	10,206	55.72	1,517.5	...	...
43	1	45.21	83.26	37.65	10,772	67.49	1,481.3	5.538	938.9
44	3	33.29	83.26	27.72	10,000	53.52	1,517.8	4,563.5	456.8
45	3.7	47.06	83.26	39.18	11,434	72.62	1,558.3	6,722.2	325
46	0	34.76	83.26	28.94	12,930	74.22	1,384.8	2,597.7	...
47	1	36.24	83.26	30.17	12,382	71.16	1,431.3	3,447	124.3
48	0	25.34	81.52	20.66	12,435	87.77	1,340.3	1,997.9	1,773
49	1	25.61	81.52	20.87	11,686	75.37	1,412.8	2,189	938.3
50	3	35.19	81.52	28.68	10,802	127.37	1,526.4	4,453.2	472.8
51	3	50.88	81.52	41.47	9,932	103.42	1,553.3	6,269.5	344.8
52	3	48.94	81.52	39.89	9,796	122.86	1,549.4	6,510	...
53	3	50.94	81.52	41.52	9,188	114.53	1,562	6,995	...
54	3	45.23	81.52	36.87	9,289	146.38	1,593	6,822	919.2
55	0	40.94	81.52	33.37	12,556	141.8	1,329.2	3,828.2	...
56	0	40.94	81.52	33.37	12,292	106.13	1,333.6	3,932.5	...
57	0	35.64	81.52	29.05	12,493	119.15	1,345	3,569.7	239.7
58	1	32.9	81.52	26.82	11,679	118.16	1,447.6	4,402	330.9
59	2	40.88	81.52	33.32	11,492	147.77	1,521.7	6,549	275.7
60	3	32.48	81.52	26.47	10,752	135.17	1,587.6	5,978.2	435.4
61	0	37.29	81.52	30.39	12,807	114.46	1,344	3,515.2	...
62	1	37.28	81.52	30.38	11,416	111.89	1,423.2	4,695.2	250.7
63	2	37.83	81 52	30.84	10,878	90.59	1,447	5,107	127.3
64	3	28.23	81.52	23.01	10,883	101.28	1,466.6	...	188.1
65	2	40.89	81.52	33.33	10,853	58 34	1,413	...	...
66	3	26.98	81.52	21.99	10,828	144.52	1,547.8	...	539.6
67	0	29.48	81.52	24.03	11,451	103.38	1,460.4	3,954.5	196.9
68	3	35.23	...	...	10,016	78.54	1,562.1	...	...
69	0	31.69	...	...	12,225	...	1,396.5	...	...

WATER-TUBE BOILER, BURNING OIL.—Continued.

No of trial.	Heat balance or distribution of the heating value of the oil.								Efficiency.	
	In British thermal units.		In percentages of the total heating value of the oil.							
	Other losses—due to unconsumed hydrogen, to heating moisture in air, to radiation, etc., by difference.	Heat value of one pound of oil, calculated from chemical analysis.	Heat absorbed by boiler.	Loss due to superheating steam used in spraying oil.	Loss due to moisture formed by the burning of hydrogen.	Loss due to heat carried away in dry chimney gases.	Loss due to incomplete combustion of carbon.	Other losses—due to unconsumed hydrogen, to heating moisture in air, to radiation, etc., by difference.	Of boiler (per cent.), [(51) ÷ (57)] × 100 = (58).	Of boiler and furnace (per cent.), (64) × $\left[1 - \frac{(33)}{100}\right]$.
1	56	57	58	59	60	61	62	63	64	65
36	...	19,481	59.11	...	...	...	...	...	59.11	55.2
37	2,181	19,481	55.66	...	7.98	24.53	.637	11.196	55.66	52.58
38	...	19,481	67.27	...	...	...	...	...	67.27	64.35
39	2,256	19,481	62.01	.43	7.63	17.78	.578	11.581	62.01	58.73
40	1,724	19,481	64.03	.42	7.78	18.5	.41	8.85	64.03	61.55
41	1,753	19,481	63.77	.336	7.52	18.22	1.157	9	63.77	61.77
42	7,702	19,481	52.39	.286	7.79	...	...	39.537	52.39	50.95
43	683	19,481	55.28	.346	7.6	28.43	4.819	3.506	55.28	53.49
44	2,889	19,481	51.34	.275	7.79	23.43	2.345	14.831	51.34	50.12
45	0	19,481	58.7	.373	8	34.51	1.668	0	58.7	56.94
46	2,494	19,481	66.36	.381	7.11	13.33	...	12.803	66.36	59.68
47	2,025	19,481	63.56	.365	7.35	17.7	.638	10.395	63.56	60.16
48	1,033	18,667	66.62	.47	7.18	10.7	9.498	5.534	66.62	59.71
49	2,366	18,667	62.62	.404	7.57	11.73	5.027	12.675	62.62	58.07
50	1,285	18,667	57.87	.682	8.18	23.86	2.533	6.884	57.87	54.07
51	464	18,667	53.22	.554	8.32	33.59	1.847	2.486	53.22	49.98
52	689	18,667	52.48	.658	8.3	34.88	...	3.692	52.48	49.03
53	807	18,667	49.23	.614	8.37	37.48	...	4.323	49.23	46.15
54	0	18,667	49.76	.784	8.54	36.54	4.925	0	49.76	46.42
55	812	18,667	67.27	.76	7.12	20.51	...	4.35	67.27	59.99
56	1,003	18,667	65.85	.569	7.16	21.07	...	5.375	65.85	60.59
57	900	18,667	66.93	.638	7.21	19.12	1.284	4.822	66.93	61.49
58	689	18,667	62.57	.633	7.76	23.58	1.773	3.692	62.57	59.42
59	...	18,667	61.57	.792	8.15	35.09	1.477	0	61.57	58.99
60	...	18,667	57.59	.724	8.51	32.03	2.333	0	57.59	55.29
61	887	18,667	68.61	.613	7.20	18.83	...	4.752	68.61	63.78
62	770	18,667	61.16	.599	7.62	25.15	1.343	4.125	61.16	58.04
63	1,017	18,667	58.28	.485	7.75	27.36	.682	5.448	58.28	55.99
64	6,028	18,667	58.3	.543	7.86	...	1.008	32.3	58.3	55.93
65	...	18,667	58.14	.313	7.57	...	...	...	58.14	56.52
66	5,607	18,667	58	.763	8.29	...	2.891	30.04	58	54.86
67	1,501	18,667	61.35	.554	7.83	21.19	1.055	8.041	61.35	58.73
68	...	...	53.67	.421	8.37	...	...	...	53.67	52.19
69	...	...	65.49	...	7.48	...	...	...	65.49	60.99

As the possibility of spraying oil by means of centrifugal force looked inviting, two burners were built for experiment. In both burners the principle of the turbine was utilized as being obviously a practicable way of securing a high rotative speed in a simple manner. These burners were designed by Mr. Harvey D. Williams, who was then Secretary of the Board.

In the burner shown in Fig. 26, the attempt was made to support the revolving part on a film of the steam discharged from the turbine buckets. This method of support was unsatisfactory, owing to some obscure action of the steam which caused the revolving part to gyrate excessively.

The burner shown in Fig. 27 was designed so as to utilize a ring of buckets that was formerly part of an experimental steam turbine. In this steam turbine there were five rings like the one used in the burner. The turbine was compounded in such a way that the outputs of power from the five rings were equal. The turbine, at a speed of 15,000 revolutions per minute, gave 20-horsepower, with a consumption of about 20 pounds of steam per horsepower hour. By the use of diverging steam nozzles the single ring, as used in the burner, should give an efficiency somewhat higher than one-fifth that of the compounded turbine. In other words, the burner turbine should, at a speed of 15,000 revolutions per minute, yield more than 1 horsepower on 100 pounds of steam per hour.

In designing the burner, however, the consumption of steam was assumed at 400 pounds per horsepower hour. This was to allow, among other contingencies, for the unknown viscosity resistance of the thin film of oil flowing from the center of the disk to the periphery. Even with this seemingly ample allowance only one-ninth as much steam should be required as in the simple jet burner.

The following brief notes, made each day during the tests with centrifugal burners, will probably best tell of the results accomplished and of the possibilities of development in this direction:

SOLID PIVOT CENTRIFUGAL BURNER.

October 27, 1902.—First official test using burner of form shown in Fig. 27 but without the large spraying disk, which was added

later. Piped for steam and oil. Steam at 125 pounds gauge pressure. Nozzles proportioned for 90 pounds gauge pressure. Turned on steam. Action of turbine and pivot very satisfactory. Turned on oil. Some oil seemed to escape from the bottom of the rotating part. Oil thrown off from milled edge was sucked downward, forming dome-shaped sheet of mist, edges of which met turbine buckets. Applied torch. Burner enveloped in flames. Flames rather gusty. Smoke varied with quantity of oil. Turned off oil and steam. Turbine ruined, half of the buckets having been ruptured by centrifugal force. The buckets were probably at a red heat, however. Buckets collided with brass nozzle tips and beveled them off.

STEAM PIVOT CENTRIFUGAL BURNER.

October 28, 1902.—First official test using burner of form shown in figure 26. Piped for steam and oil. Turned on steam. Top did not revolve. Allowed some minutes for burner to warm up to temperature of steam. Steam film afforded a frictionless support, as expected, but top would rotate only slowly. Steam orifices are too small (8,—$\frac{1}{82}$ by $\frac{1}{82}$ inches), and some of them are stopped up with dirt. Broke pipe connections. About a quart of unburnt oil on the ground where the burner stood. During the following day the steam pivot burner was dismantled, and the size of the steam passages was increased to about $\frac{1}{16}$ by $\frac{1}{16}$ inch, giving them also rounded entrances and tapered exits.

October 29, 1902.—Piped for steam and oil. Turned on steam. Top spun at a high rate of speed, but gyrated excessively. Gyration was against the rotation, *i. e.*, like that of a body whose center of gravity is below the point of support. Hence gyration was not the effect of gravitation and must have been the effect of some action of the steam. Top offered a good deal of resistance to being lifted off the pivot when rotated by steam. Resistance appeared to be at least two or three times its weight. Bushed the hole in the pivot to reduce amplitude of gyration. Gyration not prevented; only reduced. Drove a wooden plug in the oil hole and made a solid pivot. Top spun perfectly. Cut a groove in plug to allow passage of oil. Turned on steam and oil. Applied

torch. Burner worked properly. Oil ignited about 6 inches from burner. Outside diameter of flame 4 or 5 feet. Flames seemed inclined to go out when torch was withdrawn, possibly due to the wind, which was quite brisk. When not ignited the burner makes a shrill, squealing noise. When ignited there is added a roar, due to the flames. When flow of oil was increased the top was lifted as much as 3 inches from pivot and continued to spin on the jet of oil. When flow of oil was again reduced the top fell back onto the pivot without mishap.

October 30, 1902.—Made a solid step of brass for pivot to spin on, the same as in the solid pivot burner. Made a disk 10 inches in diameter of stovepipe iron and fitted it for fastening onto either burner with two ¼-inch screws.

October 31, 1902.—Both burners now having solid pivots they will be referred to as the 8-jet burner (originally the steam-pivot burner) and the double-jet burner.

The 8-jet Burner.—Piped for steam and oil. Built a cylindrical furnace 4 feet in diameter and 4 feet high of loose brick, arranged as open checker work, around the burner as a center. The plane of spray was about 14 inches above the ground. Openings were left near the ground for the entrance of air, and fire brick was built in at the level of spraying. There were 18 air openings about 6 inches wide by 8 inches high, equal 864 square inches. Behavior of top satisfactory. Turned on a very little oil and caught specimen of spray on blotting paper. Turned on more oil and ignited. Steam pressure, 80 to 90 pounds. Steam very wet. Oil pressure, 15 to 25 pounds. Oil pressure fluctuated about 5 pounds with each stroke of oil pump. Combustion occurred in puffs or gusts at intervals of two or three seconds. Gusts did not time with strokes of pump or with anything else that was noticed. Under these conditions the smoke was moderate. With more oil the gusts did not occur, but the smoke increased greatly. Oil and steam were varied by manipulation of valves with no noteworthy results. The experiment continued perhaps half an hour, until the brickwork became very hot, though not red-hot. Turned off oil and steam. Top was in perfect order and continued to spin a long time. The inside of brickwork was

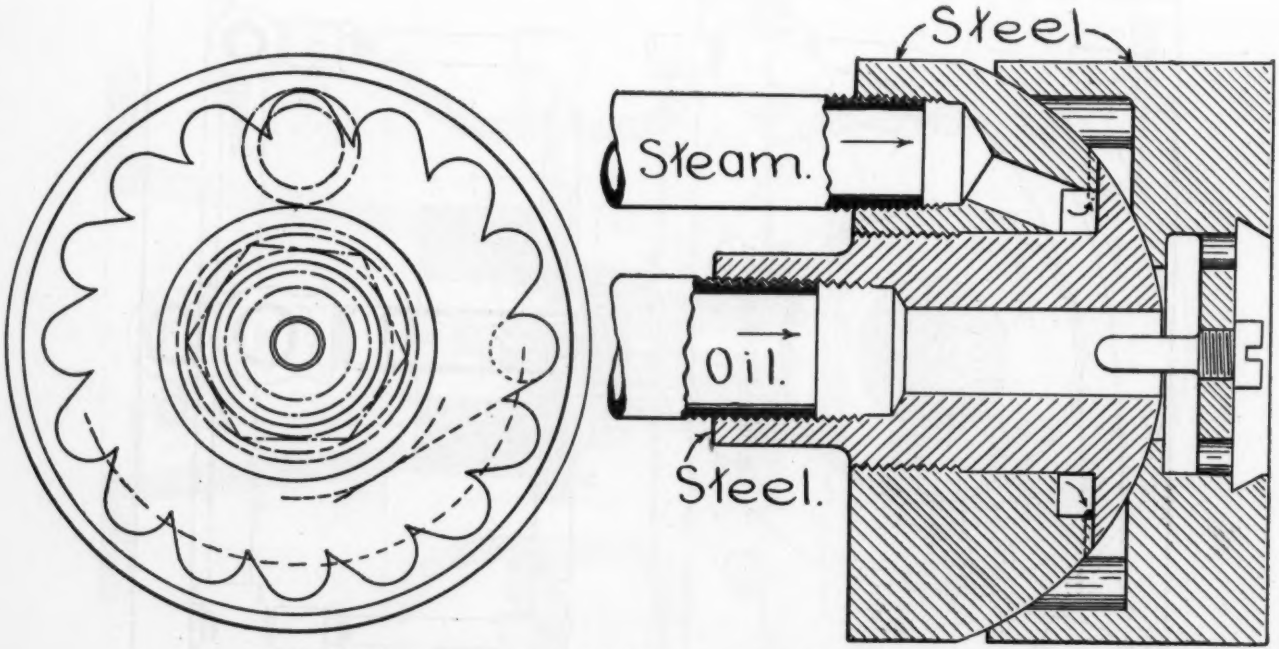


Fig. 26.—Experimental Centrifugal Burner, Steam Pivot.

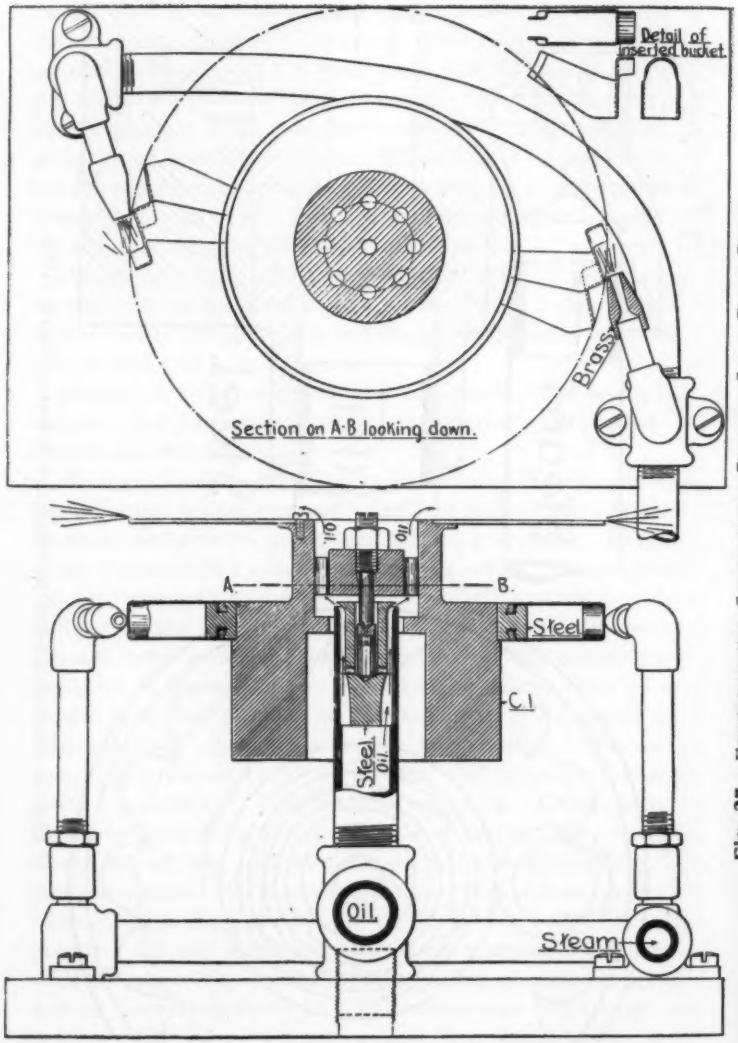


Fig. 27.—Experimental Centrifugal Burner, Solid Pivot Design.

Fig. 27.—Experimental Centrifugal Burner, Solid Pivot Design.

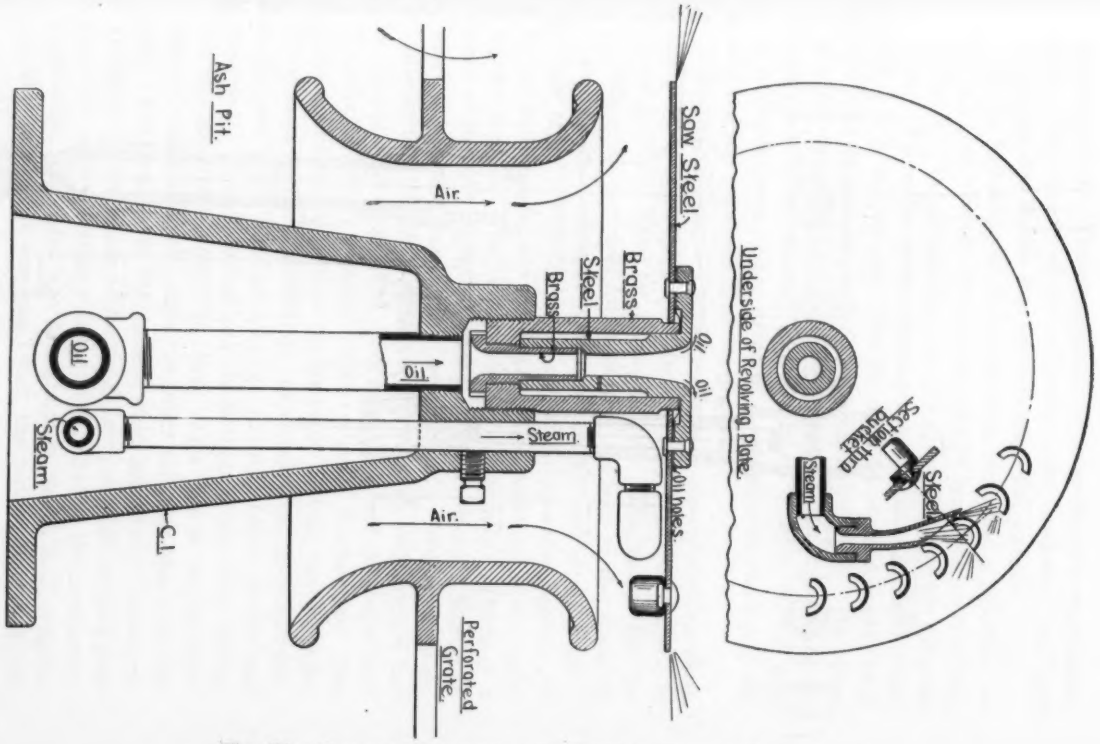


Fig. 28.—Proposed Williams Centrifugal Burner, Solid Pivot.

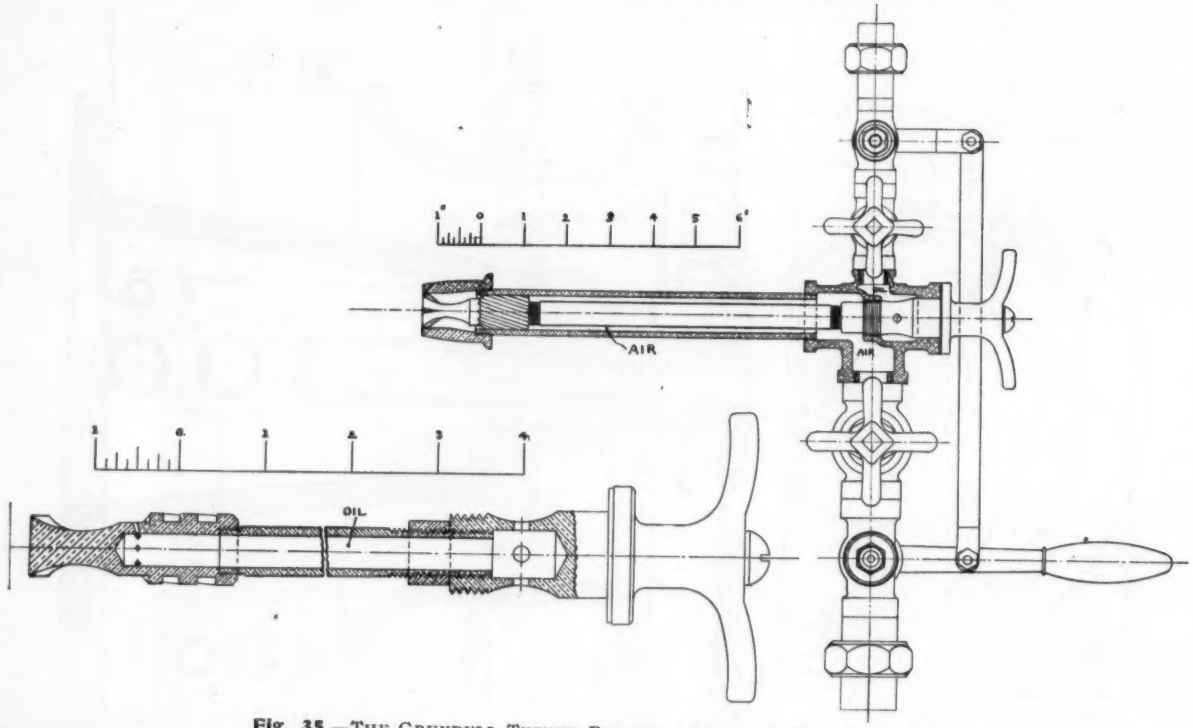


Fig. 35.—THE GRUNDELL-TUCKER BURNER, USED ON S. S. "MARIPOSA".

perfectly clean. There appears to be no tendency to deposit carbon. The outside of the brickwork was, however, black from the smoke and flames that came through the crevices.

At the beginning of the experiment there was a chimney (12 by 12 inches outside dimensions) built of loose brick around the burner from the ground up to within about 1 inch of the spraying plane. The object of the chimney was to protect the burner and piping from radiant heat. But the chimney top appeared to suck the spray downward, partly into contact with itself. The chimney was, accordingly, tumbled down with an iron rod while the burner was in operation. The result was that the oil was now all burnt, whereas before much of it collected on the top of the chimney and ran down it to the ground.

Double Jet Burner.—During the interim cleared nozzle orifices, drove on a new bucket rim, and reduced width of oil slot to about $\frac{1}{32}$ inch. Piped for steam and oil. The burner has the 10-inch sheet-iron disk for increasing the size of the spraying circle. Rebuilt furnace 4 feet in diameter and about 3 feet 3 inches high. Air openings, 18,—6 by 4 inches, equal 432 square inches. Turned on steam. The pressure at the boiler was 90 pounds. The turbine worked beautifully. Threw in a piece of burning oil-soaked waste. Turned on oil. The combustion is much better than ever before. Free from gusts. Little smoke. There is, however, no wind, a condition not had in any previous experiment. So much heat was developed that it was inconvenient to stand within 12 feet of the furnace. One could not continually stand by the steam and oil valves. After about three minutes something connected with the burner suddenly gave way. Shut off oil; the 10-inch sheet-iron disk had exploded. The oil flowed over the bottom of the disk, leaving the top unprotected from the heat. One side of the fractured disk was black with oil, while the other side was blue from the heat. The buckets of the turbine were apparently unchanged. Turned on steam again, adjusting quantity so that turbine gave about the same whistling note that it gave during the combustion experiment. A violin was brought from the U. S. S. *Rodgers*, and, after tuning, it was found that the turbine note was one

octave above the open E string. There are 32 buckets on the turbine. This makes the speed of the turbine about 2,500 R. P. M.*

November 3, 1902.—Made a disk of sheet iron $\frac{1}{16}$-inch thick and 10 inches diameter, and fastened to burner in such manner that the oil flows over its upper surface. Assembled burner and repaired circular furnace, making it 33 inches high and 4 feet in diameter. Tried burner at 5 P. M. It seemed to work satisfactorily in all respects. The oil was able to protect the disk from overheating during the few minutes that the experiment lasted. Speeded up turbine without igniting oil and caught samples of spray on blotting paper.

November 8, 1902.—Repaired brick wall. Steam at 90 pounds. Oil at 25 pounds. Turned on steam. The burner began spinning all right and soon attained speed. Ignited some kerosene-soaked waste and dropped it beside the burner. Turned on oil. There was instant ignition. Stepped aside to observe the effect. More oil was being supplied to the burner than it could take and spray properly. Much oil was escaping downward from the burner. Could not shut off the oil at the valve on account of the intense heat. Ordered it shut off at the pump. Oil continued to flow on account of the air chamber on the pump. Something exploded and demolished one side of the furnace. The turbine ring had broken loose. The ring was merely driven onto the cast-iron center. The heat and centrifugal force had been sufficient to expand it to the degree of making it loose. When free it tore off the 10-inch disk. The cast-iron center continued to spin for some time. Half the buckets were torn off the turbine ring. The 10-inch disk can be used again.

November 11, 1902.—Burner again ready for trial. A new turbine ring has been driven on and fastened with three $\frac{1}{4}$-inch screws. The 10-inch disk is fastened as before. Oil passageways through the cast-iron center have been somewhat enlarged.

November 15, 1902.—Assembled the 2-jet burner and connected

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*It was unfortunate that we had not a more reliable means of determining the speed, since this result seems questionable. The buckets of the turbine could safely withstand 15,000 revolutions per minute, and at such a speed, barring mishaps, the spraying would have been far more effective.

pipes as heretofore. Instead of a brick wall around the burner, two curved boiler plates from the scrap pile were used. The lower edges of the plates were lifted off the ground by the thickness of three bricks. The plates made an inclosure about 5 feet in diameter and 4 feet high. Turned on steam from the main boiler. Placed some oil-soaked waste on the ground within the inclosure and ignited it. Oil pump started and orders given to keep oil pressure at about 20 pounds. When the oil valve was opened there was instantly an intense combustion within the inclosure. The heat was so great that the oil supply had to be reduced. The volume of the fire was as easily controlled at the valve as in a common gas jet. After about five minutes the burner went to pieces, caused by the backing out of the supporting pipe where it screws into the pipe fitting on the pedestal.

Summary.—The steam pivot burner was a failure from the start, and it is not considered advisable to attempt to correct all its faults.

The solid pivot burner failed at first because the oil was not thrown off from its greatest diameter, and afterwards because some of the oil escaped downward and burnt underneath, thus heating the burner, and finally from the parts not being securely fastened together.

CONCLUSIONS AS TO CENTRIFUGAL BURNERS.

First. The oil should be thrown off from the largest diameter of the burner.

Second. The burner must be so arranged that the only outlet from the oil leads to the intended spraying edge. The construction of the experimental burner was such that part of the oil went wrong when the amount fed was greater than a certain maximum or less than a certain minimum.

Third. The oil should be introduced at the center of the spraying disk and flow over the whole of the surface exposed to the radiant heat.

Fourth. All parts should be secured by fastenings, which are more reliable than mere friction, however great; otherwise the very high speed of rotation will shake them loose.

Fifth. There is no evidence that the amount of oil flowing through the burner is not amply able to keep it at a safe temperature. In fact, the cooling power of the oil compared to the amount of surface of the burner is many times greater than the cooling power of water compared to the heating surface of a boiler. The ratio is from 25 to 200 or 300 in favor of the oil.

Sixth. By leading the air required for combustion in along the burner head or burner mechanism the inrush of air can itself be made to absorb much of the heat which the disk receives from radiation, the air thus constituting a cooling medium to the mechanism.

Seventh. These experiments were all conducted in the open air and some of them in a wind. Hence there was little of the benefits derivable from the presence of glowing furnace walls. How much this affected the result is, of course, uncertain, but it is the opinion of many who witnessed the experiments that the presence of hot furnace walls would have resulted in a very great improvement.

PROPOSED CENTRIFUGAL BURNER.

The designer of the foregoing burners, after careful study of the principles involved and the results of these tests, designed a new burner, which is shown in figure 28, but the construction of this burner was not completed in time to be experimented with before the conclusion of the main series of boiler tests. However, as designed, this proposed burner shows many features which it is known can be employed in forming a successful means to atomize oil by centrifugal action.

In this burner but one disk is used, this disk constituting both the spraying edge and the medium to carry the steam turbine buckets. The buckets are riveted to the disk of saw steel in a circle 1 inch within the edge of the disk. The steam turbine nozzle is located within the circle of buckets, and blows its steam outwards, as shown in the upper part of the figure. To gain economy in steam consumption the precise form of the De Laval nozzle or tuyere is used, which nozzle it may be said has the property of increasing the velocity of the issuing steam to its highest point, and the buckets passing within this jet of high

velocity have imparted to them the energy derived from the jet. The amount of steam used is so small that one jet should be amply sufficient to exert all the centrifugal force required to effect the necessary vaporization with oils of usual consistency. The pivot itself is arranged so as not to require any outside lubrication, this being effected by a small by-pass of the oil to the outside sleeve of the fixed pivot.

The fuel oil, under a slight pressure from the pump, is caused to pass up through the center of the mechanism to the top of the spraying head. It is here caught by the rapidly whirling disk and flung away with high velocity from the revolving edge. This passage of oil over the disk constitutes in a measure a cooling jacket to protect the metal of the disk from the intense radiation of the furnace from above. Cooling on the under side of the disk is effected by taking in a portion of the air supply through a flared opening in the grate immediately under the revolving disk. The action of the furnace draft, together with the steam blast created by the steam tuyere, tend to produce a sharp flow of air immediately under the rapidly revolving portion of the disk.

The burner as thus constructed would naturally be regulated by controlling the oil supply, the entrance of steam being kept at a point to insure the maximum rotation of the disk.

In the practical introduction of these burners into fire boxes they would probably be located in the center of grates of square fire-box furnaces, and the air supply would be brought in, as indicated, mainly around the burner, and additional air, as needed, through proper openings in the grate. For purpose of use in furnaces of Scotch boilers it would be desirable to place the rotating head in the end of the furnace casting, and require the disk to revolve in a vertical plane. With small-size Scotch furnaces it would be necessary to reduce the diameter of the disk and increase the speed of rotation by use of one or more steam jets.

EXTENT OF RESEARCH WORK AND INVESTIGATION CONDUCTED BY THE BOARD.

In the investigation of the important problem of attempting to determine the value of liquid fuel for naval purposes the Board

made special effort to note the development as regards the use of liquid fuel secured by the industrial and maritime world. The oil-fuel installations of several ocean-going steamers were carefully examined under actual working conditions. The installations projected by various promoters were critically inspected. The operation of various patented oil-fuel devices installed at several industrial establishments were reported upon, so that the Board could ascertain, by comparative observation and study, the trend of development of oil burning under various conditions both for manufacturing and marine purposes.

Hundreds of letters have been received from technical experts throughout the country, and the conclusions reached by the Board represent a vast amount of research, investigation and experiment. The Board can unhesitatingly state that both upon the part of the engineering profession and of skilled labor there is a general desire to have oil supplant coal as a fuel for practically every purpose. The prejudice in favor of oil is so great that it is strikingly significant that the general public is told very little concerning the disadvantages, but is repeatedly reminded of every advantage accruing from the use of oil as a fuel. The desire to use liquid fuel thus practically exists everywhere. When manufacturers, however, attempt to secure some guaranty that the numerous promises made as to reduced cost and assured supply will turn into performances, then become manifest the hindrances to the use of oil as a fuel. It may also be said that up to the present time, except upon the Pacific Coast and in certain portions of the East Indies, the more carefully shipowners inquire into the financial, structural and transportation features of the oil-fuel problem, the less inclined they are to dispense with the use of coal in the furnaces of their boilers.

THE OIL-FUEL INSTALLATION OF THE STEAMSHIP "MARIPOSA."

The Board believes that the observation and report of Lieut. Commander Ward P. Winchell, U. S. Navy, as to the installation of oil-fuel appliances on board the steamship *Mariposa* should be considered in connection with this extended series of tests, since the data secured in regard to the performance of that

vessel were collected with exceeding care, this officer having made the round trip on the vessel as the representative of the Bureau of Steam Engineering, Navy Department.

The extent and character of the information secured by this officer suggests the advisability of detailing other officers for special duty of this nature. The Board is of the opinion that if several commissioned officers could be employed continuously in this work for one or two years there could be secured sufficient reliable information to justify the Department taking decided action as to the advisability of exclusively equipping even a large-sized warship with an oil-fuel installation.

The Board, after making inquiry, has been impressed with the number of officers who are ready to volunteer for such work, and who are specially fitted for this particular duty, and there is no doubt but that naval interests would be subserved by such details.

As it can be expected that several mercantile vessels will make the round voyage between the Pacific and the Atlantic coast during the coming year, using oil exclusively as a fuel, the Board specially recommends that arrangements be perfected whereby a commissioned officer could be detailed to the special duty of observing and reporting upon the effectiveness of every oil-fuel installation subjected to such extended service.

THE VOYAGE OF S. S. "MARIPOSA," USING AN OIL-FUEL INSTALLATION EXCLUSIVELY UNDER HER BOILERS.

The following is a description of the steamer *Mariposa*, of the Oceanic Steamship Company, as fitted for oil-fuel burning, with an account of the preliminary trial trips of the vessel as witnessed by Captain H. N. Stevenson, U. S. Navy; also the report of Lieut. Commander Ward P. Winchell, U. S. Navy, who officially represented the Department on the round trip of the steamer between San Francisco and Tahiti.

REPORT OF CAPTAIN H. N. STEVENSON, U. S. NAVY, ON THE OIL-BURNING FITTINGS OF THE S. S. "MARIPOSA."

The *Mariposa* is a single-screw iron steamer, built at the yard of William Cramp & Sons, Philadelphia, Pa., in 1883. She re-

cently had new engines and boilers installed by the Risdon Iron Works, San Francisco, Cal., the oil-burning plant having been installed by the same company.

This vessel has been employed in the Pacific trade, and is now running to Tahiti from San Francisco, making the round-trip voyage of 7,320 knots each month.

DESCRIPTION OF THE "MARIPOSA."

Gross tonnage	3,160
Length between perpendiculars, feet	314
Beam, feet	41
Mean draught, feet	22
Depth of hold, feet	$17\frac{3}{12}$

There is a single bottom with four watertight athwartship bulkheads, and two masts, square rigged on the foremast.

The total crew was formerly 81, but since the change from coal to oil burning 16 men have been taken out of the engineer's force, reducing the crew to 65 men and making the engineer's force for oil burning 20 men, as follows: 1 chief engineer, 3 assistant engineers, 3 oilers, 1 electrician, 1 attendant for ice machine, 1 attendant for air compressor, 3 water tenders, 6 firemen, 1 storekeeper; total, 20.

THE ENGINES AND BOILERS.

There is one triple-expansion engine of the inverted direct-acting type, with cylinders 29 inches, 47 inches and 78 inches by 51-inch stroke, designed for 2,500 indicated horsepower, fitted with piston valves on the high-pressure and intermediate-pressure and slide valve on the low-pressure cylinders, all driven by link motion. The condenser is part of the back framing. The cylinders are not jacketed.

The air, feed and bilge pumps, of which there are two sets, are driven from the forward and after crossheads. The centrifugal circulating pump is driven by a separate engine. The 4-bladed propeller is 16 feet 6 inches diameter and has a pitch of 23 feet.

There are three cylindrical tank boilers placed fore and aft in the line of the ship—two are double ended, 15 feet 3 inches dia-

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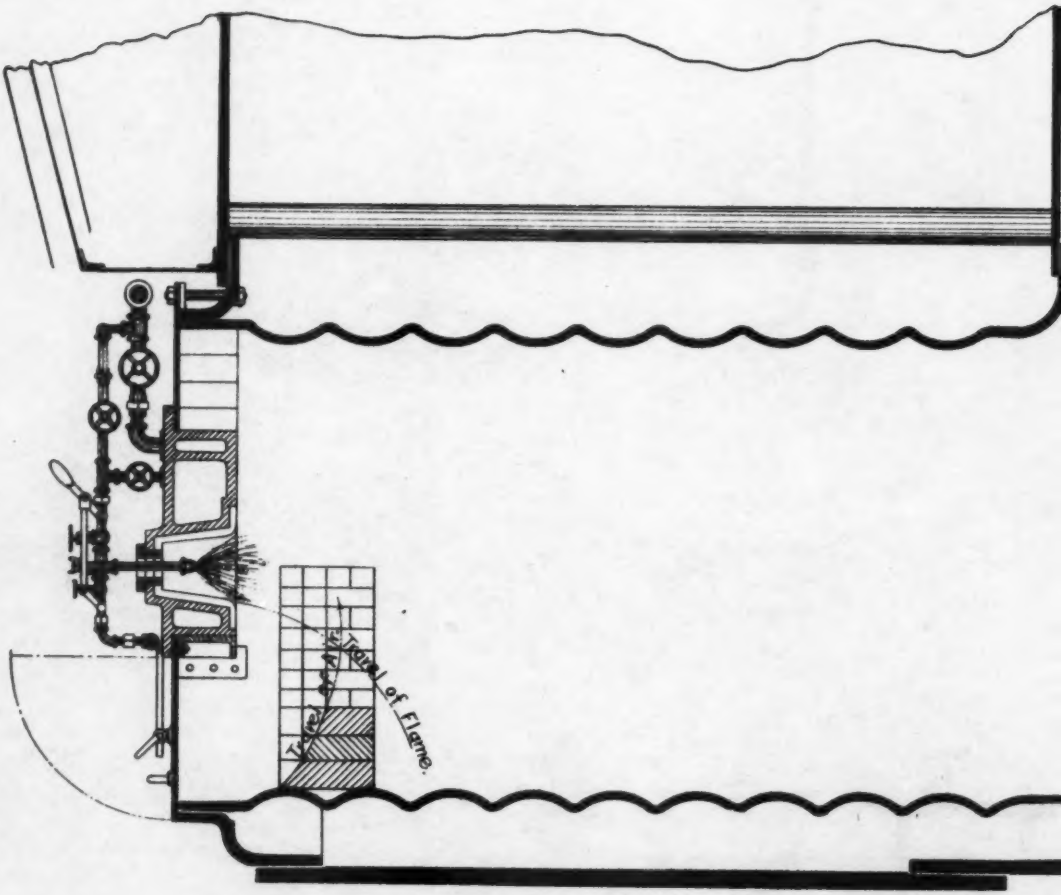
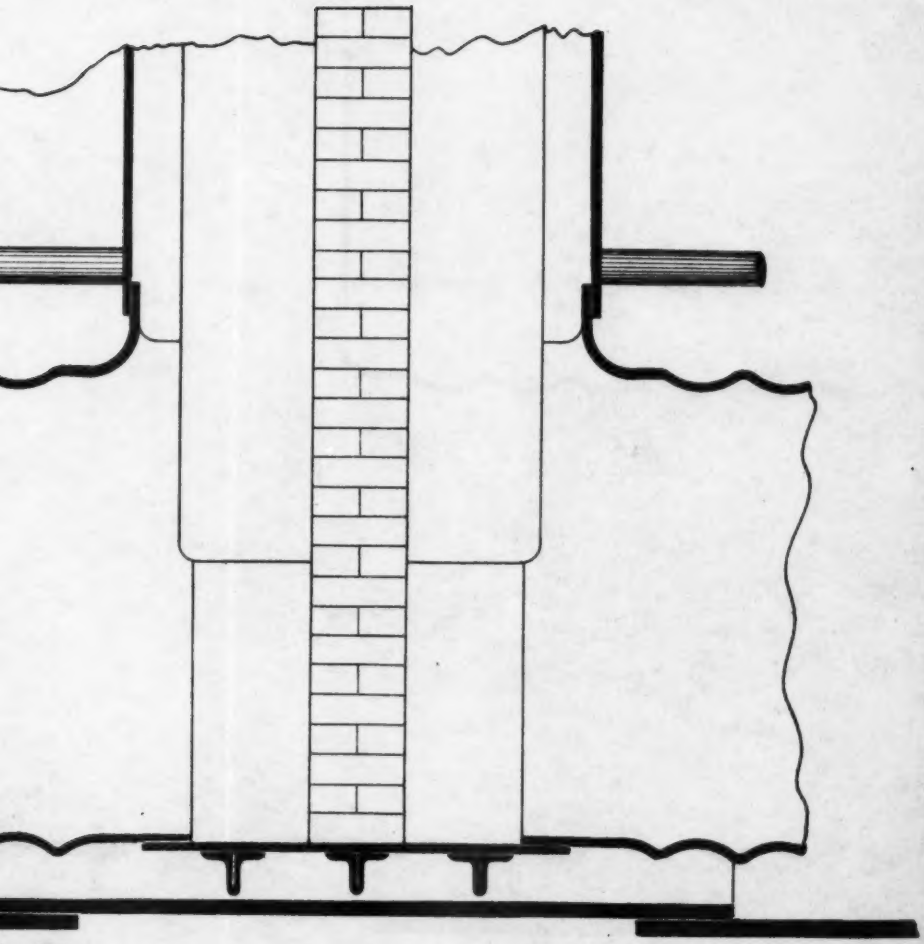


Fig. 36.
ARRANGEMENT OF FURNACE FOR MEC



ig. 36.
E FOR MECHANICAL BURNER.

meter by 17 feet 3 inches long, and one single-ended, 14 feet diameter by 9 feet 9 inches long, the latter placed amidships forward of and worked from the forward fireroom. Each double-ended boiler has six corrugated furnaces; the double-ended boilers have a common combustion chamber for opposite furnaces, while the single-ended one has a common combustion chamber for its three furnaces. There is one smokestack for all the boilers. The combustion chambers of the double-ended boilers have a brick bridge wall, and the back sheet of the single-ended one is covered with fire brick. The decision to use oil in place of coal was not made until the changes in engines and boilers were well under way, and it was decided to put the ship on the route to Tahiti. The steam pressure averages 180 pounds. There is one auxiliary boiler, two-furnace return-tube type, in upper fireroom hatch, and fitted to burn coal only.

The Oil Tanks.

These were constructed out of the old coal-bunker space forward of the boilers, and as the steamer is intended to carry oil for the round trip of about 7,320 miles some additional space had to be taken from the forehold. They are arranged as follows: Just forward of the boiler space a solid watertight bulkhead, well braced, was built from the berth deck to the single bottom of the ship, extending to the single skin of the ship, from side to side; 4 feet, or two frame spaces, forward of this was also built another similar solid bulkhead, which formed the after ends of the oil tanks; 48 feet farther forward another similar solid bulkhead was built to form the forward ends of the oil tanks, and 4 feet forward of this another solid bulkhead. The spaces of 4 feet at each end of the tanks being a cofferdam space to catch any oil from leakage or accident, these cofferdam spaces can be filled with water if necessary. The tank space is divided into six tanks by a middle bulkhead and two side partitions. Splash plates to break the impact of rolling are placed in each tank, a small opening at the top allowing any accumulation of gas to pass off to the ventilating trunk. Small openings at the bottom allow

free communication for the oil. Along the top of the tanks is provided an expansion head or trunk, being 4½ feet high and 4½ feet wide. Over each a ventilating trunk connecting with the top of each tank extends up to about 5 feet above the hurricane deck. The cofferdam spaces are ventilated by tubes reaching to the upper deck, fitted with cowls, one tube reaching to near the bottom to carry off any heavy gas that might accumulate there. From the upper deck the sounding pipes to each tank are reached. There are no pipes in or through the tanks except those connected with the oil service. The total capacity of the tanks, exclusive of expansion trunk, is 6,338 barrels of oil—about 905.43 tons. One barrel of oil equals 42 gallons.

To fill the tanks, a 6-inch hose connection is fitted on the port side outside the ship. From this a pipe leads to the forward fireroom, where the tank oil pump is placed. This pump, horizontal duplex, steam cylinders, 9 inches, oil cylinders, 8½ inches, stroke, 10 inches, can be used to draw its supply from the pipe and deliver into each of the tanks, or by using by-passes, which are provided, the oil barge alongside can fill all the tanks. An overflow pipe from each tank, carried at height of the deck above them, leads to an overflow outside the ship near the supply-hose coupling.

There are two service or settling tanks placed in pockets formed on either side of the single-ended boiler. They are reached by doors from the forward fireroom. Each of these tanks holds about twelve hours' supply. They are filled by the oil-tank pump and have overflows back to the main tanks. Ventilating tubes lead from near the bottom of the pockets in which they are placed to the smokestack.

Each service tank is provided with glass gauges, by means of which the amount used every hour or watch can be easily measured.

Each settling tank has two suction pipes, one at bottom to draw off water if necessary, the other at the height of about two feet for the oil supply to the service pumps. All the tanks are provided with manholes to reach the interior.

The Oil-Service Pumps.

The oil-service pumps, of which there are two—horizontal duplex, steam cylinders, 6 inches, oil cylinders, 4 inches, and stroke of 6 inches, one being large enough to supply all the burners—are placed in the forward fireroom on either side. They draw their supply from the settling or receiving tank through removable strainers placed so they can be easily changed for cleaning, and discharge into the bottom of the small heating tank near them, where the oil is heated by a steam coil to not more than 150 degrees Fahrenheit, and thence by a pipe to the burners. The air from the compressors, under a pressure limited to 40 pounds, discharges into the top of the heater tank on its way to the burners, so that the oil and the air go to the burners under the same pressure. The heater tank is provided with glass gauges; also a float to work a telltale and automatic control of oil-supply pump.

The Air Compressor.

The air compressor is placed in a pocket off the upper engine-room platform, and consists of duplicate steam and air cylinders connected to a crank shaft carrying a fly wheel turning between the cylinders. Either set is large enough to supply all the air necessary. The air compressor is horizontal, double-acting, duplex. Air-cylinders, 22 inches, steam cylinders, 12 inches diameter, by 18-inch stroke for all cylinders. Capacity equals 1,000 cubic feet of free air per minute compressed up to 30 pounds at 120 revolutions per minute. Air is used at the heat of compression or as heated by the air heater.

The Atomizer.

The atomizer, for which patents are pending, is the joint invention of Messrs. Grundell and Tucker, San Francisco.

The atomizer, shown in Fig. 35, consists of a hollow plunger for the oil, screwed into a pipe through which the air passes. The outlet for the oil is through a series of small holes at right angles to the central hole; the air meets the oil through spiral

directors and is sprayed into a rose shape by the expanded end of the atomizer.

The air and oil pipes have globe valves to regulate the supply of either; also plug-cocks connected together to a handle, by means of which each burner can be shut off immediately, in case of necessity—a slow-down bell, or other cause. The air-supply pipe is also connected to the steam line so that steam can be quickly substituted for air, if desired. The length of the oil plunger is adjustable, to give the best form to the rose-shaped flame. Two burners are fitted to each furnace.

The Air Heater.

A part of each furnace front is a hollow iron casting, through which the air passes on its way to the atomizers and becomes heated. The chamber surrounding the burner is lined with a crucible lead lining; a by-pass to the burners is provided for use in case of accident to the heater. The lower part of the furnace front is a door on hinges that can be fastened open at any desired degree to give air for combustion. There are also two louvres in the door for the same purpose. Near the front of the furnace inside the door is placed a brick wall made to deflect upward the inward current of air to meet the rose-shaped flame from the burners. There is ample space over the brick wall for a man to enter the furnace through the ash-pit door. The double furnace combustion chambers have a brick bridge wall reaching above the top of the furnaces, and in the single-ended boiler the common combustion chamber has the back sheet covered with fire brick to protect it.

The Trial Trips.

Two trial trips with the vessel under way were made on July 5 and 11, the vessel being under way about eight hours each day, running from the vessel's dock to the Farallone Islands and return. These trips were made for the purpose of ascertaining if the oil apparatus, as well as the new engines and boilers, were in good working condition. On the first run the boilers primed badly, owing to the dirt not having been thoroughly cleaned out

of them. Before the second run the boilers were cleaned, and then worked well.

The strainers on the oil-supply pipes were not finished, and considerable trouble was found with dirty oil, which clogged the burners. Neither the telltale to show the height of oil in the heater tank nor the controlling device for the oil-service pump were fitted, not being finished in time for use. No attempt was made to measure the amount of oil burned nor to attain the maximum speed, and it was therefore impossible to obtain any data other than observation of the working of the oil apparatus.

Very few of the fireroom force had ever had any experience with oil burners on steamers, and one object of the trials was to give the force practical experience. When properly regulated the burners gave no smoke, but that they were not properly regulated is shown by the fact that more or less smoke was visible most of the time, and at times dense black. Owing to lack of the telltale and regulating device of the small heating tank the pump tender once allowed this tank to fill up and the oil to flow over into the air pipe and flood the burners. As soon as this was discovered every burner was immediately shut off by means of the lever connecting to the plug cocks on the oil and air-supply pipes at the burners.

The atomizer tubes were unscrewed, and on some of them, where the oil had caked, considerable force had to be applied to pull them out. New, clean atomizers were screwed in, and as soon as the oil-heater tank could be brought to the proper oil level the burners were started again. Some steam pressure was lost during this delay, but the engines did not stop nor slow down very much; some of the burners were started in a few minutes and all of them in less than fifteen minutes. The value of being able to shut off the oil and air quickly and clean or substitute other atomizers was shown by this mishap. The burners made considerable roaring noise, and the air pressure was, in order to clean the burners from dirt, carried at about twice the intended pressure, owing to the inefficiency of the strainers, which allowed dirty oil to choke them. They had to be taken out frequently for cleaning. By shutting off with the lever, the regu-

lating valves were left in adjustment for starting the fire again, provided it was right before. The new fire is started by a torch inserted into the plug hole around the burner.

On the second run, the strainers and regulating device for the heater tank had been completed. The oil apparatus was handled with greater ease and uniformity, and the less amount of smoke was very noticeable. For intervals of an hour or more scarcely any or none would be observed. On the run in from the Farallones the engine was speeded up to 74 to 77 turns, and an average speed of 14¼ knots was obtained. The steam pressure was uniformly maintained at the point desired without difficulty, and the oil-burning apparatus gave no trouble whatever and worked well.

The oil used on both runs was from the Kern River district, near Bakersfield, Cal.

The following data were observed:

Steam pressure, pounds	160–170
Revolutions of engine	74–77
Revolutions of air compressor	60
Pressure of air, pounds	20
Temperature of oil entering heater, degrees Fahrenheit	80
Temperature of oil leaving heater, degrees Fahrenheit	120–130
Temperature at base of stack, degrees Fahrenheit	750

It is regretted that the nature of the trials did not permit of obtaining a greater amount of data beyond observing the apparatus in use.

The chemist at the New York Navy Yard submitted the following report upon the sample of the Kern River district oil sent him for analysis:

"The sample is practically free from low boiling naphtha, as on distillation only a small percentage passed over below 150 degrees centigrade, and less than 10 per cent. below 225 degrees centigrade. A boiling point above 360 centigrade was reached before the second 10 per cent. was collected.

"It shows on ultimate analysis the following composition:

	Per cent.
Carbon	84.43
Hydrogen	10.99
Nitrogen	.65
Sulphur	.59
Oxygen	3.34

"This gives a calorific value, by Dulong's formula, of 18,806 B. T. U. The specific gravity at 60 degrees Fahrenheit is 0.962. Flash point, 228 degrees Fahrenheit. Fire point, 258 degrees Fahrenheit. Vaporization point, 178 degrees Fahrenheit. Loss for six hours at 212 degrees Fahrenheit, 12.01 per cent."

H. N. STEVENSON,
Captain, U. S. Navy.

REPORT OF LIEUTENANT COMMANDER WARD WINCHELL ON THE VOYAGE OF THE "MARIPOSA."

U. S. S. BOSTON,
AT SEA, *August 15, 1902.*

Sir: In accordance with the Department's telegraphic order of July 7, 1902, delivered July 8, 1902, and the instructions from the Bureau of Steam Engineering, dated July 7, delivered a few minutes before sailing, I took passage on the Oceanic Steamship Company's steamer *Mariposa*, leaving San Francisco at 10 A. M., July 15, 1902, for the round trip to Tahiti.

In accordance with the instructions of the Bureau, two sets of indicator cards were taken each day, making forty-five sets in all, the data of which were worked up.

There have been no tests to determine the evaporative efficiency of the two main double-ended boilers used on the run, and I regret to report that the chief engineer of the ship was unable to improvise any apparatus by which the amount of feed water could be determined with accuracy enough to give data of any value.

The amount of oil is a matter of much importance, since the tanks hold barely enough to make the round trip, and but one day's supply of coal was aboard. The oil was measured first by the amount pumped into the two settling tanks, as shown in inches on the scale back of the gauge glasses on the tanks; second, this amount was checked by the number of inches used out of each tank for each watch; third, another check, and the one considered most accurate as dealing with large quantities and small errors, was by sounding the tanks from time to time and comparing the amounts taken out with the expenditures in

the log. The latter method gave a correction which was applied to the daily log, increasing the daily expenditure slightly, as summed up by inches in the settling tank.

The most careful inspection at Tahiti failed to show any bad effect of the flame upon the boilers. Neither leaks nor defects developed anywhere about them and there was no difficulty at any time in feeding the boilers. Having been ordered to the U. S. S. *Boston* immediately upon my arrival at San Francisco, the opportunity was lost for again inspecting the boilers, but no defects showed from the outside. At Tahiti the tubes were swept by tube scrapers, and back connections, uptakes, ash pans and furnaces were cleaned. All the refuse from these various places barely filled two ash buckets.

This refuse, mainly soot, was the result not only of the twelve days' run to Tahiti, but also of the three preliminary trials by the contractors. The first one, a four-hour trial of engines and boilers, was made with Comax coal, and the other two were free runs at sea, of about eight hours' duration each, burning oil. The tubes had never been cleaned previous to arrival at Tahiti. It is the intention hereafter to make the round trip of twenty-four days' steaming without sweeping tubes.

There are no precautions, other than those usually taken on board ship, to guard against fire or explosion. All spaces to which oil has access are well ventilated by both inlet and outlet ducts. The oil is a thick, dark fluid, like molasses, and in the open air burns slowly, giving off much smoke. But it gives off volatile gases which form explosive mixtures with air, tanks empty or nearly so being more dangerous than full ones in this respect. The ship is electrically lighted, but in addition an open hand lamp is burning in the fireroom all the time to light the burners; the firemen smoke on watch, and the oil is treated no more tenderly than if it were coal. On the run back, the cargo of copra was stored all about the expansion trunk, which projects up 4½ feet between decks, completely covering the tanks and making them inaccessible for examination.

Of the six firemen, three were relieved from watch the second day out, leaving but one man on a watch to fire twelve furnaces in

two different firerooms separated by the length of the double-ended boilers. The water tender did not touch the burners except in emergency, his duty being to 'tend water, fill settling tanks and record height of oil in them, record temperatures of oil at settling tank and in heater of fireroom and of superheated air, take reading of lower pyrometer where the two uptakes meet, and run oil pump supplying oil to the settling tanks, and small oil pump supplying oil to the oil heater.

As a coal burner the *Mariposa* formerly had the following engineer force: 1 chief engineer, 3 assistant engineers, 3 oilers, 12 firemen, 12 coal passers, 3 water tenders, 1 messenger, 1 storekeeper; total, 36.

A reduction of sixteen men in the fireroom force is effected by oil burning. At sea she needs now but three firemen, but carried six. This would reduce the force by nineteen men.

Temperatures of firerooms seem to be about what one would expect in coal burning, but the temperatures of the uptake and smoke-pipe gases run high, the maximum being 925, which shows an undue loss of heat here. The temperature of the oil in the settling tanks ranged between 68 degrees and 100 degrees Fahrenheit on the trip out and between 90 degrees and 108 degrees Fahrenheit on the trip back.

The oil auxiliaries comprise 1 large oil pump, 2 small oil pumps, 2 oil heaters, 1 air compressor and 4 strainers.

There is a steam-pipe connection to blow out the oil strainers, and another one to blow out the oil burners when clogged.

On August 3 the air compressor needed overhauling, and steam atomizing was kept up for two and one-half hours until the compressor was again working. During this time the evaporator supplied enough feed water to use 20 burners; the engines were not stopped while shifting from steam to air atomizing, and averaged 67.8 turns for the two and one-half hours. They had before been making 70 turns.

At first two firemen and a water tender were on watch at a time, each fireman having 1 fireroom of 6 furnaces, or 12 burners. The men had but little experience, combustion was poor, much smoke was made, much oil burned and poor speed attained. To locate

the responsibility for bad adjustment of burner valves but one fireman was put on at a time to attend 12 furnaces (24 burners). This made an improvement in the combustion.

Unfortunately, the top of the funnel can not be seen from either fireroom, and while the fireman can tell by the appearance of the flame as shown in the sight hole, or even by the roar of the burner, when the combustion is perfect, in designing a boiler room for liquid fuel the ventilators should be so arranged that a view of the top of the smoke pipe can be had from each fireroom.

The work of the fireman would be even easier than it is and better results attained if the oil and air pressure were kept constant and the heated temperature of the oil constant. The apparatus then, once properly adjusted, would need very little change. To get these results is a mere matter of detail easily arranged. If the temperature of the oil rises it feeds more freely and a readjustment is necessary, and the same conditions hold with regard to the pressure.

It will be noticed that in addition to the independent oil and air supply valves the burners are fitted with an air-plug cock and an oil-plug cock connected to one lever, which then controls both air and oil supply, enabling the operator to shut them both off at once in emergency. At first, when steam went up too high and a burner was shut down, this lever was used; but shutting off the air thus gave the air compressor less work, and as its governor is not sensitive the air pressure increased, making a readjustment of all oil and air supply valves necessary, with consequent smoke. Later on, when it was desirable to shut down a burner, the oil alone was shut off by the independent feed valve on the burner, and the untouched air valve kept the air compressor's work more nearly constant; then when the burner was again required the oil valve was opened and immediately lighted from the flame of the adjacent burner.

In starting fires with everything cold, steam is raised on the auxiliary boiler, which burns coal, and the air compressor, oil pumps and oil heater are started. The oil is lighted by inserting oil-soaked rags in the air space surrounding the burner and

touching a lamp to them, or an arrangement like a gas lighter may be used.

Sometimes when the air pressure is too high, or insufficient oil is feeding, the flame flickers and may go out. If the oil is kept feeding under these conditions, on relighting there is a small explosion of the gases in the furnace, with a momentary back draft through the peep holes and ash pans.

When shut down July 19, for two and one-half hours, plugging condenser tubes, one burner at each end of each boiler (4 burners in all), furnished steam to run all auxiliaries, including feed pump, bilge pump, air compressor, ice machine, dynamo and flushing pump, all of which were exhausting into the atmosphere.

During the four days in port at Tahiti the forward main single-end 3-furnace boiler was used, atomizing with steam. Generally two burners in the middle furnace gave ample steam to run the following auxiliaries, all exhausting into the atmosphere, with boiler fed from fresh water on the dock: Ice machine, dynamo, flushing pump, feed injector, two cargo winches, and small portable steam pump.

In the Grundell-Tucker burner (see Fig. 35) the oil, heated by a steam coil under boiler pressure throttled down, passes through the inside pipe and is thrown out radially through the series of small holes. The air, first heated by compression up to 20 pounds, is further heated to a temperature of about 350 degrees Fahrenheit in the air chamber surrounding the burner and called the "air superheater." Air can be used at the temperature at which it leaves the compressor, and was so used on the trip down until July 17, when the superheaters were connected up. This air under the pressure of about 20 pounds surrounds the oil pipe in the burner and passes axially along the pipe until near the end, where it is given a whirling motion through small helical passages arranged like the rifling of a gun. It crosses axially and whirling through the fine oil streams spurting radially from the end of the burner, breaking up the oil into fine spray, the drops of which can be seen before they ignite. A further air supply (cold) is admitted through the hinged door of the ash pan, and is directed up across the path of the flame and heated

also by a curved fire-brick wall built in the ash pan close to the front.

The ash-pan door is not moved much, but the regulation of the air supply is by the valve control of the air and oil in the burner. The flame should be a steady, full, white or yellowish white one, filling the furnace.

The principal difficulties encountered were in the regulation of the supply of oil to the heaters by the pump and the consequent variation of the temperature of the heated oil and the freedom of flow through the burners. An automatic submerged float, arranged like a steam trap and fitted in the oil heater to control the throttle of the pump, failed to give good automatic results, and the supply of oil was regulated by hand. If the oil is heated too much (above 150 degrees Fahrenheit), some of the volatile gases are given off and mingle with the air pressing on top of the oil in the heater, thence passing with the air into the air superheaters and burners, the result being that on one occasion a heater got red hot from this cause.

Another difficulty was due to the choking of the strainers by foreign matter and impurities in the oil, shutting off the supply of oil, and on one occasion (August 10) putting out all the fires. Just previous to the fires going out, and while the usual air supply was on, and an insufficient amount of oil being fed, a dense white smoke, like steam, arose from the funnel.

This strainer difficulty will be solved by fitting the strainers in pairs, so that a clean one can always be switched in while the choked one is being cleaned.

Generally the revolutions of the engines did not vary much during the day, and in calculating the horsepower for each day's average revolutions, when the cards for that day differed much, that set was selected whose revolutions were near the average for the day, with the indicated horsepower assumed to vary as the cube of the revolutions. If the two sets of cards for the day had the same number of revolutions their average indicated horsepower was used as a basis to compute the day's horsepower as before.

It will be noted that the log accompanying this report is kept

from noon to noon. This was done as the patent log was inaccurate, and the speed of the ship was got from noon positions as given by sights.

It will be noted that speed was much higher on the return trip than on the outgoing, which is ascribed partly to the better combustion, as the firemen became more experienced, partly to the overhauling of the bearings at Tahiti by the force on board, and mostly to the increased oil consumption allowed after the run down had proved that there was plenty of oil for the return trip, which was a matter of some doubt before, the ship being provided with coal for twenty-four hours to cover possible emergency.

Full power was not developed in the two boilers used, as schedule time was easily exceeded with from 2 to 4 burners shut off, though it would not appear, from the tabulated results, that the indicated horsepower would equal what can be got by a good system of forced draft. This burner, however, works well with the Howden system of forced draft, as seen on the tank steamer *George Loomis*, plying on a Pacific coastwise route from southern California to San Francisco.

It must be remembered that the tabulated calculations are all based on the indicated horsepower of the main engines only, as it was considered better to use only data actually obtained, and afterwards estimated data, such as indicated horsepower of auxiliaries, could be applied without vitiating the observed data and results. No cards could be taken from any of the auxiliaries, but careful estimates give the following results:

	I.H.P.
Air compressor, at 60 revolutions per minute	110
Auxiliary feed pump and two oil pumps, one in intermittent use	30
Dynamos	30
Ice machine	7
Circulating pump	5
Flushing pump	2
Baths, steam tables, evaporator, cooking, &c.	11
Total	195

The steering engine is not used except near port.

The size of air compressor was based on the assumption that

it requires 1 cubic foot of free air for every pound of water evaporated from and at 212 degrees Fahrenheit, as shown by tests of various oil burners at Western Sugar Refinery, San Francisco.

The weights of oil auxiliaries are as follows:

	Tons.
Air compressor	9
Two settling tanks	12
Two oil heaters	2
Two oil pumps (small)	.5
One oil pump (large)	1.25
Fifteen superheaters (air), front	3.1
All pipe, valves, fittings, ventilators, etc	8

It should be remembered that the boilers were designed for coal burning; that the oil-burning plant was fitted in a hurry, the machinists not leaving the ship until the gong rang for people to go ashore, that the firemen were without experience in oil burning, and that most of the automatic gear did not function properly.

With the air pressure constant, with the oil heated at constant temperature near 140 degrees Fahrenheit, with oil strainers arranged in pairs, so that one is always efficient, and with experience in firing, the results in economy of oil should be much better on the next trip; and the fireman's work, already very easy, will approach supervising automatic regulation. The fireman for oil does not need strength nor previous training with coal. He should have a good eye, good ear, some common sense, and a desire to learn a new and easy trade.

In conclusion, it is desired to state that every facility for investigation was given by all the officers of the company, the chief engineer of the ship being particularly zealous in arranging for the taking of required data.

Very respectfully,

WARD WINCHELL,
Lieutenant, United States Navy.

To the CHIEF OF BUREAU OF STEAM ENGINEERING,
Navy Department, Washington, D. C.

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GENERAL AVERAGES OF LOG OF "MARIPOSA" BURNING OIL, ROUND TRIP, SAN FRANCISCO AND TAHITI, JULY AND AUGUST, 1902.

	San Francisco to Tahiti, July 16–26, 1902.	Tahiti to San Francisco, August 1–11, 1902.	Average, two runs.
Knots, per day	312.7	334.9	325.7
per hour	13.12	14.05	13.58
Revolutions per minute	65.2	70.91	68.05
I.H.P. main engines only	2,193	2,770	2,481
Oil, total, barrels	2,803	3,277	6,080
used per day, barrels	254.8	302	278.4
total tons of 2,240 pounds	400.43	468.14	868.57
used per day, tons of 2,240 pounds	36.4	43.18	34.29
hour, pounds	3,412	4,026	3,719
Grate surface, two double-ended boilers	258	258	258
Heating surface, two double-ended boilers	8,302	8,302	8,302
I.H.P. main engines per square foot of grate	8.593	10.73	9.661
pound of oil per hour	.643	.688	.665
Square feet of heating surface per I.H.P.	3.786	3	3.393
Pounds of oil per hour per I.H.P.	1.556	1.45	1.503
knot run	260.9	286.3	273.6
Knots made per ton of oil	8.585	7.818	8.201
barrel of oil	1.22	1.111	1.165
Slip of screw in per cent	13.14	12.8	12.97
Actual time, hours and minutes	262·57	260·31	261·44
Knots, total	3,438	3,660.1	3,549

For convenience in comparing with engineer's log, the day is taken from noon until noon. July 16 begins at noon July 15 and ends noon July 16. This leaves but two hours' run on July 15, which was thrown out of the calculations. The average indicated horsepower of main engines was obtained not by averaging the daily runs, but by taking average revolutions for the eleven days' run, and taking the cards near these revolutions as a basis in computing the horsepower.

* * * *

A study of the comparative results of the first, second and seventeenth voyages will show that even on the first voyage an oil-fuel installation on marine vessels can be operated with a fair degree of success with a comparatively inexperienced crew. It will be observed that, comparing the general results secured on the seventeenth voyage with that of the first and second voyages, a slight increase in efficiency has been secured. (See table, page 810.)

ABSTRACT OF LOG OF STEAMSHIP "ALAMEDA," PLYING BETWEEN
PERFORMANCE BETWEEN

Coal Fuel (*machinery*

No. of the voyage.	Outward or homeward.	Length of voyage.		Main engines. Pressures.			Vacuum, in inches.	Average distance made each day of 24 hours.	Fuel per day.		Air pressure for atomizing.	Gravity of oil, Baumé.	Burners in use.
		Days.	Hours.	Boiler.	First record.	Second record.			Coal, in tons.	Oil, in barrels.			
102	Outward	6	9	175	...	...	25	323	71.04	...	...	...	...
102	Homeward..	6	6	177	...	...	25	331	66.48	...	...	...	...
103	Outward	6	1	175	...	...	25	343	68.88	...	...	...	...
103	Homeward..	5	19	178	...	...	25	357	71.76	...	...	...	...
104	Outward	6	2	175	...	...	25	340	67.68	...	...	...	...
104	Homeward..	5	22	175	...	...	25	350	71.28	...	...	...	...
105	Outward	5	19	175	...	...	25	356	73.92	...	...	...	...
105	Homeward..	6	...	174	...	...	25	346	73.92	...	...	...	...
106	Outward	6	1	164.5	...	...	25	343	64.8	...	...	...	...
106	Homeward..	5	23	175	...	...	25	347	73.68	...	...	...	...
107	Outward	6	5	154	...	...	25	348	68.88	...	...	...	...
107	Homeward..	5	23	170	...	...	25	348	74.16	...	...	...	...
108	Outward	5	23	171	...	...	25	349	69.12	...	...	...	...
108	Homeward..	5	22	174	...	...	25	350	80.88	...	...	...	...
109	Outward	6	4	163	...	...	25	339	68.64	...	...	...	...
109	Homeward..	5	21	171	...	...	25	353	74.88	...	...	...	...

Oil Fuel (*machinery only in fair adjustment,*

113	Outward	5	17	174.5	40.1	12.1	26	362	...	349	16 9	14.2	30
113	Homeward..	5	20	175	487	14	27	356	...	388	14.5	14.4	30
114	Outward	5	17	174	65.9	14.1	27	365	...	352	15	14.6	30
114	Homeward..	6	...	175	76	17	26	348	...	391	16	14.5	30
115	Outward	5	20	175	55	12	25	355	...	341	11	14.4	41
115	Homeward..	5	21	175	62	15	25	350	...	379	14	14.2	35
116	Outward	5	21	164	49	6	24	352	...	281	10	14.3	30
116	Homeward..	6	2	175	64	8	24	343	...	344	13	14.3	36
117	Outward	5	23	174	51	5	24	349	...	298	14	14	36
117	Homeward..	5	23	175	56	7	24	348	...	343	12	13.8	42
118	Outward	5	21	175	55	4	24	353	...	307	9	13.9	41
118	Homeward..	5	22	175	58	6	24	350	...	319	10	13.6	42
119	Outward	5	22	175	56	5	24	353	...	317	10	13.6	42
119	Homeward..	5	23	175	62	6	24	348	...	331	10	13.8	42

SAN FRANCISCO, CAL., AND HONOLULU, HAWAII, SHOWING COMPARATIVE COAL AND OIL.

only in fair adjustment).

Temperature.							Percentage of ash in coal.	Remarks.
Injection.	Discharge.	Feed.	Engine room.	Fireroom.	Superheated air.	Base of smoke stack.		
...	...	...	...	...	...	...	22.1	These eight voyages were made with coal as a fuel; with the ship having a new installation of boilers and engines. These runs cover a period during which the motive plant had not the opportunity to demonstrate its efficiency as when the machinery had reached its best working condition, as it probably did at a later date. The coal used was a mixture of the British Columbia and Australia production. Its evaporative efficiency under a test boiler (Scotch) was about 7.75 pounds of water per pound of fuel from and at 212 degrees Fahrenheit. It will be observed that the percentage of ash was quite high. As the vessel experienced both favorable and unfavorable conditions as regards weather during these eight voyages, it may be presumed that the data furnished is sufficient in quantity to give average results. The actual distance traveled was 33,154 miles, and 6,878 tons of coal were consumed in the boilers of the ship. It therefore required 465 pounds of coal to drive the vessel 1 mile in distance.
...	...	...	...	...	...	...	17.5	
...	...	...	...	...	...	...	17.2	
...	...	...	...	...	...	...	17.1	
...	...	...	...	...	...	...	24.5	
...	...	...	...	...	...	...	20	
...	...	..	...	...	...	...	18.2	
...	...	...	...	...	...	...	19 4	
...	...	...	...	...	...	...	20.7	
...	...	...	...	...	...	...	18.9	
...	...	...	...	...	...	...	16.7	
...	...	...	...	...	...	...	21.6	
...	...	...	...	...	...	...	21.4	
...	...	...	...	...	...	...	17.1	
...	...	...	...	...	...	...	20.2	
...	...	...	...	...	...	...	23.9	

inexperienced men operating burners).

63	90	210	85	101	390	536	...	These were the first seven voyages made by the vessel where oil was used as a fuel. The crew were comparatively inexperienced in the operation of an oil-fuel plant, and therefore the best results were not secured. While making these seven round trips with crews practically inexperienced in the operations of the oil burners there was consumed for steaming purposes 28,183 barrels of oil. The distance made by the ship was 29,078 miles. In comparing this performance with the results secured when burning coal it will be noted that the relative efficiency of oil fuel and an inferior grade of coal was thus found, after extended test under conditions stated above, to be in the ratio of 1 to 1.42. This comparison is based upon the standpoint of weight. As a pound of oil costs less in San Francisco than a pound of any grade of coal suitable for marine purposes, the economy of using oil fuel in the steamship *Alameda* is thus clearly apparent.
63	95	210	82	94	390	635	...	
64	104	210	84	104	393	630	...	
63	100	205	81	91	385	608	...	
63	99	209	87	107	420	576	...	
63	101	208	77	97	405	557	...	
65	99	209	84	101	415	475	...	
66	100	201	83	99	396	444	...	
66	103	106	88	111	388	436	...	
68	105	208	85	110	383	453	...	
68	110	208	86	111	375	460	...	
71	110	208	92	112	377	593	...	
68	110	209	95	115	388	480	...	
68	110	208	90	100	391	443	...	

ABSTRACT OF LOG OF STEAMSHIP "ALAMEDA," PLYING BETWEEN
PERFORMANCE BETWEEN

Oil Fuel (*machinery well adjusted,*

No. of the voyage.	Outward or homeward.	Length of voyage.		Main engines. Pressures.			Vacuum, in inches.	Average distance made each day of 24 hours.	Fuel per day.		Air pressure for atomizing.	Gravity of oil, Baumé.	Burners in use.
		Days.	Hours.	Boiler.	First record.	Second record.			Coal, in tons.	Oil, in barrels.			
124	Outward	5	21	175	51.8	4.8	25	353	...	300	9	13.9	45
124	Homeward..	5	18	175	53	5	25	362	...	314	9	13.2	45
125	Outward	5	21	160	56	6	25	355	...	310	9	14	45
125	Homeward..	5	21	160	53	5	25	353	...	310	9	14.1	45
126	Outward	5	20	175	52	5	25	353	...	307	9	13.9	45
126	Homeward..	5	21	171	51	4	25	355	...	281	9	13.4	45
127	Outward	5	18	174	58	8	25	360	...	340	9	13.4	45
127	Homeward..	5	23	175	59	8	25	350	...	334	9	13.4	45
128	Outward	6	20	175	50	4	25	355	...	298	8	13.9	45
128	Homeward..	5	6	175	59	7	25	331	...	355	8	13.8	45
129	Outward	5	21	174	52	4	25	355	...	274	8	13.9	45
129	Homeward..	5	21	175	55	6	25	358	...	305	8	13.7	45
130	Outward	5	20	175	55	6	25	355	...	312	8	14	45
130	Homeward..	5	21	175	53	6	25	353	...	307	8	13.4	45
131	Outward	5	21	175	57	8	25	353	...	336	8	14	45
131	Homeward..	5	21	175	51	7	25	355	...	293	8	13.6	45

SAN FRANCISCO, CAL., AND HONOLULU, HAWAII, SHOWING COMPARATIVE COAL AND OIL.—Continued.

burners efficiently operated).

Temperature.							Percentage of ash in coal.	Remarks.
Injection.	Discharge.	Feed.	Engine room.	Fireroom.	Superheated air.	Base of smoke stack.		
70	106	208	95	107	405	476	...	During these eight voyages the machinery department was in such a state of efficiency that the best possible results ought to have been secured. The crew had also become experienced in the operation of an oil-fuel plant. The results of these voyages may be compared with the performances of the *Mariposa*, bearing in mind that the *Alameda* runs on a faster schedule than her sister ship, the *Mariposa*. When burning a slightly refined California oil product with an experienced crew in the fireroom, and with machinery in good condition, there was consumed for steaming purposes during these eight round trips 29,363 barrels of oil. The distance made by the vessel on those voyages was 33,229 knots. There was, therefore, required 300 pounds of oil fuel to drive the ship a distance of 1 knot. The relative consumption of oil, as compared with an inferior grade of coal, is therefore in the ratio of 1 to 1.55. It will likewise be noted that not only was a more uniform pressure carried in the boilers with oil as a fuel, but that the average time required to make the voyage was reduced a few hours.
69	110	210	90	104	393	500	...	
69	109	210	93	113	410	465	...	
67	108	210	88	105	398	446	...	
67	109	210	93	109	405	456	...	
66	109	210	90	107	405	423	...	
66	107	211	90	104	408	457	...	
66	109	212	89	96	400	457	...	
66	108	212	93	108	393	408	...	
65	108	206	87	99	376	457	...	
64	108	212	88	104	395	423	...	
63	108	212	89	112	398	408	...	
64	107	212	91	107	383	408	...	
63	106	212	90	111	366	426	...	
65	105	212	87	102	358	435	...	
64	108	212	89	116	366	433	...	

COMPARATIVE PERFORMANCES OCEANIC STEAMSHIP MARIPOSA, USING OIL AS FUEL.

Outward Trip.

Date.	Voyage No.	Knots per day.	Knots per hour.	Revolutions per minute.	Barrels oil per day.	Oil per day, in tons of 2,240 pounds.	Oil per hour, in pounds.	Pounds of oil per knot.	Knots per ton of oil.	Distance per barrel of oil, in knots.	Slip, per cent.	Average temperature, uptake (°F.).	Average temperature, superheater (°F.).
July, 1902.....	1	312.7	13.12	65.2	254.8	36.40	3,412	260.9	8.585	1.22	13.14	...	...
August, 1902.....	2	309.9	12.96	63.4	226	32.28	3,013	233.3	9 60	1.37	9.9	548	360
February, 1904...	17	302.2	12.80	61	217	31	2,893	229.7	9.716	1 39	7.3	425	388

Homeward Trip.

August, 1902.....	1	332.7	14 05	70.91	302	43.18	4,026	286.3	7.818	1.111	12.8	...	...
September, 1902..	2	304.9	12.7	65.7	241	34.46	3,212	252 6	8.87	1.27	13.01	546	360
March, 1904.....	17	308.4	12.8	61.9	221	31.57	2,946.5	229.3	9.76	1.395	9.1	463	383

There has also been received from the administrative officials of the Oceanic Steamship Company the abstract of the steam log of twenty-three voyages of the steamship *Alameda*, a sister ship of the *Mariposa*. During eight of these voyages coal was used as a fuel. On seven of the trips the machinery was only in fair adjustment, and an inexperienced crew operated the oil-fuel plant. During eight other voyages with an oil-fuel installation the machinery was in an excellent state of adjustment and operated by an efficient crew. A careful study of the data of this steamship will give some of the most reliable information as to the relative efficiency and economy of a coal and oil fuel plant on a merchant vessel. (See tables, pages 806–9.)

THE OIL-FUEL INSTALLATION OF THE STEAMSHIPS "NEVADAN" AND "NEBRASKAN."

The attention of the Board had been specifically directed to the oil-fuel installation of the steamers *Nevadan* and *Nebraskan* of the American-Hawaiian Steamship Company. As the steamship *Nebraskan* of this line had made the voyage from New York to San Diego, California, with coal as a fuel, and had made

the return trip from San Diego to New York with an oil-fuel installation, the Board regarded it as of importance to inspect the installation of the vessel as early as possible after her arrival in New York.

Through the courtesy of Capt. W. D. Burnham, the manager of the line, the Board made a personal examination of the installation of this vessel just after the arrival of the ship in port from San Diego, the vessel having made only one stop for a few hours at Sandy Point, Straits of Magellan, on the voyage from the Pacific coast.

The *Nebraskan* left New York, August 7, 1902, touching at the ports of St. Lucia, British West Indies, and Coronel, Chile, for coal. She reached San Diego in fifty-seven days, five hours and forty-three minutes. On that voyage 2,267 tons of coal of poor quality were used, and a fireroom crew of fifteen men was found necessary. The ship was kept at full speed during the entire voyage.

On the voyage from San Diego to New York, with a greater cargo in her hold, the voyage was completed in fifty-two days, seven hours and twenty-six minutes. There were consumed in the furnaces on this voyage 8,826 barrels, or 1,260 tons, of California fuel oil. Only six men were required in the fireroom. Their wages approximated $50 per month each.

On the outward passage from New York to San Diego the ship steamed 13,280 miles, while on the homeward passage between San Diego and New York the ship steamed 12,760 miles, the increased distance on the outward passage being due to the fact that the ship called at both St. Lucia and Coronel for coal.

Four hundred and fifty-seven tons of measured space for cargo was saved by reason of the oil fuel being of less bulk. The resulting financial gain to the company from all causes was at the rate of $500 per day. While five days were saved on the eastward journey, it must be remembered that that voyage was 520 miles shorter.

The insurance risks, both on the vessel and on the cargo, were not increased with the installation of liquid-fuel appliances. The underwriters made careful examination of the arrangements for

storing the oil fuel, as well as the general character of the oil-burning installation, and after special investigation regarded the equipment as one not constituting an element of danger sufficient to demand higher insurance rates.

In order to detect and collect any leakage of oil a cofferdam had been constructed both forward and aft of the principal fuel-oil bunker. At the end of the journey no leakage of oil had been observed. The oil used was from the California wells, a product which had undergone a light distillation, thus making it less explosive and less harmful to bunker and boiler plates.

In past years it had been observed that very injurious effects were produced upon the ends of boiler tubes and on the seams of plates with the use of crude petroleum as fuel. The experience of the superintending engineer of this line, Mr. Lassoe, is that when oil is slightly refined its use is less harmful than in the case of coal to all parts of the boiler, providing the liquid fuel is burned in a proper manner.

When firing boilers with coal as a fuel the firemen have necessarily to keep the furnace doors open a considerable time in order to secure efficient results. When the doors are opened for working a coal fire the cold air rushes in, and it is a fair estimate that the heat of the furnace during this time drops as much as several hundred degrees. With such extreme and rapid changes of temperature there must be a tendency of plates and even of tubes to contract, and attendant injury to the boiler often ensues. With the use of oil as a fuel it was found that the furnace doors did not need to be open during the entire journey, and a more constant heat was thus obtained throughout the boiler. The full efficiency of the boiler is therefore more likely to be secured with the use of oil than with the use of coal as a fuel, and this has been evidenced in the steamers of this line by the more uniform pressure noted on the steam gauges.

The comparative results secured with coal and oil as a fuel by the *Nebraskan* when making long voyages are strikingly shown in the table, page 814. When making the first voyage to the Pacific coast, coal was used in the furnaces. On the return trip from the Pacific an oil-fuel installation was in operation. It will

be noticed that the displacement of the vessel on these three long voyages was about the same, consequently the relative evaporative efficiency of the two kinds of oil, as well as of coal with oil, can be clearly established. While the coal used on the westward voyage was of an inferior grade, the hull of the ship was in much fouler condition on the voyage eastward, and these are factors that must be considered in determining comparative results.

Special attention is directed to the comparative data secured on the voyage from San Diego to New York, where California oil was used as a fuel, with the voyage between New York and San Francisco, where the Texas product was used as a combustible.

During the passage from New York to San Francisco, however, where the Texas product was used as a fuel, the vessel encountered very severe weather in the South Atlantic. Before entering the Straits of Magellan on this voyage the ship was almost hove to for two or three days.

The Howden draft system proved a decided advantage in the burning of the Texas as well as the California product. With this arrangement of utilizing the heat of the waste gases, no cold air is admitted to the furnace, thereby minimizing the fluctuation of temperatures in the boilers. On several occasions the temperature of the escaping gases at the base of the stack was as low as 375 degrees Fahrenheit, which indicates that complete combustion took place in the proper places.

While the general information received from the officials of the American-Hawaiian Steamship Company concerning the performance of the *Nebraskan* is of exceeding value, it is essential for military-naval purposes that more data in regard to details of installation and operation of the machinery of these ships be supplied the Navy Department. The Board therefore suggests that a commissioned officer be detailed to make the voyage between the Atlantic and Pacific coasts on one of these steamers. There is no doubt but that an observing officer would succeed in collecting information concerning the burning of fuel oil that would be of the utmost value to a more thorough and complete knowledge of the fuel question. The time may be nearer than

SUMMARY OF PASSAGES OF THE AMERICAN-HAWAIIAN STEAMSHIP "NEBRASKAN;" ALSO ONE VOYAGE OF THE STEAMSHIP "NEVADAN," A SISTER SHIP, OF THE SAME DIMENSIONS AND ENGINES.

	Using coal, New York to San Diego.	Using California oil fuel, San Diego, Cal., to New York.	Using Texas oil, New York to San Francisco.	Using California oil as fuel, San Francisco to Seattle.	Using California oil as fuel, San Francisco to Honolulu.	S. S. *Nevadan* using oil as fuel, Kahului, Hawaiian Islands, to San Francisco.
Time of voyage..... days	57	32	54	2	6	8
hours	5	5	6	23	22	6
minutes	43	3	42	13	43	10
Time under way..... days	53	51	52	2	6	8
hours	20	7	11	21	22	6
minutes	20	26	27	19	28	10
Stoppages during voyage.... days	3	...	...	...	...	...
hours	9	21	4	1	...	...
minutes	23	37	11	54	Pilot 15	...
Total engine rev. during entire voyage,	5,393,430	5,455,060	5,545,780	319,595	820,880	907,610
Revolutions:						
Per mile.....	406.1	428.65	422.21	393 5	393	445.7
Per minute.....	69.5	73.83	73 39	76.83	82.18	76 3
Time out of dock..... months	2	6	2	...	...	5
days	22	3	...	9	...	...
Draught of vessel:	*ft. in.*	*ft. in.*	*ft. in.*	*ft. in.*	*ft. in.*	*ft. in.*
Leaving port ..... forward,	24 8	25 1	25 2	12 11	18 2	24 3
aft	24 3	25 0	25 10	17 10	20 10	24 11
Arrival at port ..... forward,	21 7	21 8	21 6	12 8	17 4	23 6
aft	22 6	21 9	22 6	17 5	20 3	24 10
Mean draught:						
During voyage..... forward,	23 2½	23 4½	23 4	12 9½	17 9	23 10½
aft.....	23 4½	23 4½	24 2	17 7½	20 6½	24 10½
Even keel.....	23 3½	23 4½	23 9	15 2½	19 1½	24 1½
Displacement, tons.....	8,300	8,417	8,576	5,184	6,700	8,900
Distance run by ship, knots.....	13,280	12,726	13,135	812	2,088	2,036
Distance run by propeller, knots	15,076	15,252.34	15,496	893	2,294	2,536.8
Average speed of ship, knots.....	10 27	10.33	10.43	11.76	12.54	10.2
Average speed of propeller, knots	11.66	12.38	12.30	12.9	13.78	12.75
Average slip, per cent.....	11.9	16.56	15.2	9.11	9	20
Indicated horsepower:						
Main engines.....	1,635	1,986	2,010	1,875	2,325	2,190
Auxiliaries (estimated).....	210	210	210	175	200	200
Total.....	1,845	2,196	2,220	2,050	2,525	2,390
Fuel consumption:						
Main engines (coal), tons	*a* 2,269	...	...	...	...	...
Main engines (oil), barrels.....	...	7,982	8,771.26	372	1,289	1,400
Auxiliaries (oil), barrels.....	...	844	916.40	94	111	140
Total (oil), barrels	...	*b* 8,826 / *b* 9,126	9,687 66	466	1,400	1,540
Per hour (coal), pounds.....	*c* 3,773 / *d* 4,091	...	...	...	...	...
Per hour (oil), barrels.....	...	7.17	7.69	6.66	8.4	7.77
Per I.H.P. (oil), pounds.....	2	1.10	1.12	1.07	1.12	1.09
Miles per ton of coal..... Eureka...	6.16	...	...	...	...	...
Coronel ..	5 53					
Miles per barrel of oil.....	...	1.44	1.36	1.742	1.48	1.35
Air pressure, ins. of water in fireroom,	...	.8	.8 to .9	½ to ⅝	.5	1⅛
Air pressure for atomizing, pounds.....	...	1.5	1.25	1¼	1.2	1¼
Temperature of oil in heater, °F.....	...	150	90	150–160	175	175
Temperature at base of stack, °F.....	...	490–500	430–450	500	575	510
Kind of fuel used	Coal.	*e*	*f*	*e*	*g*	*e*
Gravity of oil.....	...	*h*	*i*	*j*	*k*	*l*
Temp. of oil received on board, °F.....	...	90	42	100	80	94
Tons of fuel carried.....	2,267	...	...	...	...	1,260

a Eureka-Coronel. *b* Plus evaporator and detentions. *c* Eureka. *d* Coronel.
e California slight refined. *f* Texas residuum. *g* California 15° Baumé.
h 15° Baumé at 60° F. *i* 22½° Baumé at 60°F *j* 16° Baumé. *k* 9655=8.04 lbs. per gal.
l 16.4° Baumé at 60° F.

now realized when the Navy Department may be called upon to suddenly equip auxiliary war vessels, if not fighting ships, with oil-burning devices. There would be a saving of both time and expense in effecting such installation by continuing the investigation of the fuel-oil problem along every line where new data might be procured.

There are also shown the logs of two intermediate voyages of this vessel, one from San Francisco to Seattle and one from San Francisco to Honolulu. The performance of the ship when making these intermediate trips is introduced in order to establish the fact that practically uniform results are secured in marine installations when using oil as a fuel.

The log of the *Nevadan*, when studied in connection with her sister ship the *Nebraskan*, will show that similar and equal results have been obtained on the two vessels. The *Nevadan* has now traveled 70,000 miles with oil-burning appliances, and practically no repairs have been made to her boilers since the oil-fuel installation was introduced.

The percentage of slip of the screws on the outward voyage from New York to San Diego was 11.9, while the slip on the voyage from San Diego to New York averaged 16.56. This difference is explained by the fact that the steamer leaving New York on the outward passage had been in dry dock and had been painted immediately before sailing, while the ship had been four and one-half months in the water when sailing from San Diego, the greater part of that time having been spent in San Francisco Bay, fitting out for stowage of oil fuel in double-bottom tanks; also from the fact that the vessel experienced considerably more adverse currents on the homeward passage than the outward from New York. The weather conditions may also have had something to do with the question of the slip of the propellers. Considering the great length of the two voyages, and the extended period during which both fuels were continuously used, the comparative information obtained ought to be regarded as exceedingly reliable and valuable.

On the voyage of the *Nebraskan* to New York the ship had but little reserve of fresh water, since it was found difficult to

obtain the required amount at San Diego. The vessel, therefore, on the voyage from the Pacific coast had to use her evaporator for forty-five days, while on the voyage from the Atlantic coast, with only a poor quality of coal in her bunkers, she left New York with a reserve of fresh water amounting to about 150 tons.

It was found that, in addition to the cost in fuel of effecting sufficient evaporation to make up for the loss of fresh water, there was also a loss in steaming efficiency due to the priming of the evaporators. The scant complement detailed for firerooms made it almost impossible to keep close watch on the evaporators, and therefore at times, in rough weather, salt water was carried over from the evaporators. If it had not been that the ship had a reserve of fresh water in the compartments beneath the fire and engine rooms when starting from New York, the vessel would have used 50 tons more coal on her outward voyage to San Francisco.

The following list of auxiliaries gives the diameter, stroke, and number of cylinders, and the indicated horsepower for each, roughly estimated.

Classification.	Size of cylinders.	Cylinders.	I.H.P.
	inches.		
Steering engine	7 by 7	2	3
Dynamo engine	6½ by 5	1	8
Refrigerating engine	9 by 8	2	9
Circulating engine	6 by 6	2	16
Blowing engine	9 by 12	2	26
Fan engine	5 by 4	4	16
Feed pumps	8 by 5 by 10	4	16
Ballast pumps, pumping oil from double bottom	7 by 10½ by 10	2	5
Brine pumps	6 by 5½ by 6	2	3
Oil pumps, for burners	5½ by 3½ by 6	2	2
Evaporator pump	3 by 3	2	1
Total I.H.P.	....	..	105

The miles per barrel of oil depend, of course, upon the displacement or weight propelled.

As these auxiliaries use fully 30 pounds of steam per indicated horsepower, or more than double that of main engines, they have

been estimated at 210, so as to have but one average of oil per indicated horsepower in summary of log.

A statement of the comparative engine-room complement when using coal and oil, is interesting as showing the considerably reduced force required for oil burning. It will be strikingly suggestive, however, that rather higher technical ability is required for the oil-fuel conditions. As tersely expressed by the managing director of the line, "With an oil-fuel installation there is required trained furnace men rather than old-time stokers, while the coal passer has disappeared altogether."

The engine-room complement of the steamship *Nebraskan* when using oil consisted of one chief engineer, three assistant engineers, six oilers, three furnace men, three wipers to assist furnace men, one deck engineer.

The regular watch when the ship was underway consisted of one engineer, two oilers, one furnace man, one wiper.

When using coal on the voyage from New York there were five men on a watch in the fireroom instead of two, as in the case with oil fuel.

While it is possible to do without the "wipers" in the fireroom, it has been considered safer to carry these extra men in the boiler room. There was always a probability of one of the three furnace men becoming incapacitated, and therefore the work would have been too onerous if the furnace men had ever been compelled to stand watch and watch. The "wiper" rendered efficient service in helping to look out for the compressors and various pumps, and, as it requires some practice to efficiently operate the burners, the best interests of the company were subserved by having such a rate included in the complement of the fireroom force. As the pay of the "wiper" is about double that of a coal passer, the actual gain as regards the pay of the fireroom force when using oil and coal is more apparent than real.

As to the hull of the ship, it was observed that the slightly refined oil was rather a preservative of the steel, since the oil contained a small quantity of asphaltum. As sulphur and other corroding agents are sometimes contained in the coal, the oil is not at a disadvantage as respects corrosion of the hull plate.

In the oil-fuel installation of the *Nebraskan* the oil is pumped to a heating tank and brought to a temperature of 175 degrees Fahrenheit. It is then forced at a pressure of 15 pounds to the atomizer, where it mixes with heated air, supplied at a pressure of 1¼ pounds. An exceedingly fine spray results, and in that manner it is burned.

Every portion of the machinery operating the oil-burning installation is in duplicate. An irreparable breakdown is therefore almost impossible. On the return voyage to San Francisco the fuel supplied was from the Texas oil fields, and therefore the relative value of that oil can be compared as to thermal value and ease of operation with the California product.

An examination of the profile of the ship (figure 38) will show that in vessels of such length there are but slight, if any, structural disadvantages to be encountered as regards stowing oil fuel as compared with the difficulties to be encountered in the case of armored cruisers and battleships. In the case of naval construction the ship is of comparatively short length, and the construction of a bunker extending the full width of a ship and extending to the main deck would be a practical impossibility by reason of the installation of the protective deck as well as by the interference of various gun mountings and ammunition hoists.

* * * *

The general characteristics and construction of the burner are shown in the accompanying sketch (figure 37). The marked feature of the appliance is the fitting of a plug at the discharge end of the burner, whereby the oil is introduced into the furnace through a series of radial holes rather than through a central orifice. The drilling of numerous spiral holes in these plugs influences the length and character of the flame, and from the actual operation of the burners it can not be doubted that combustion is thereby effected near the front of the furnace rather than amid the tubes or within the smoke stack.

The distinguishing features of the general oil installation of the *Nebraskan* are as follows:

(*a*) Although the burner is so designed that either steam or

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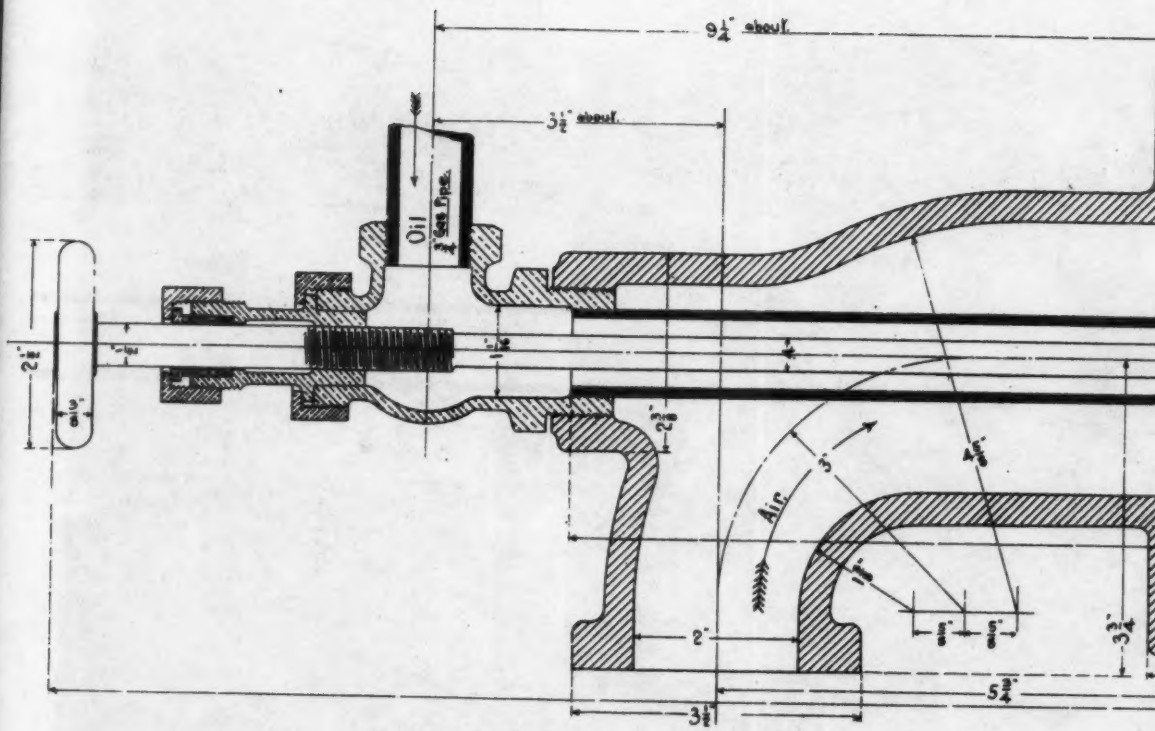

9¼" about.
3½" about.
Oil
¼" Gas Pipe.
Air
5"
4⅝"
2"
3¼"
5¾"
3½"

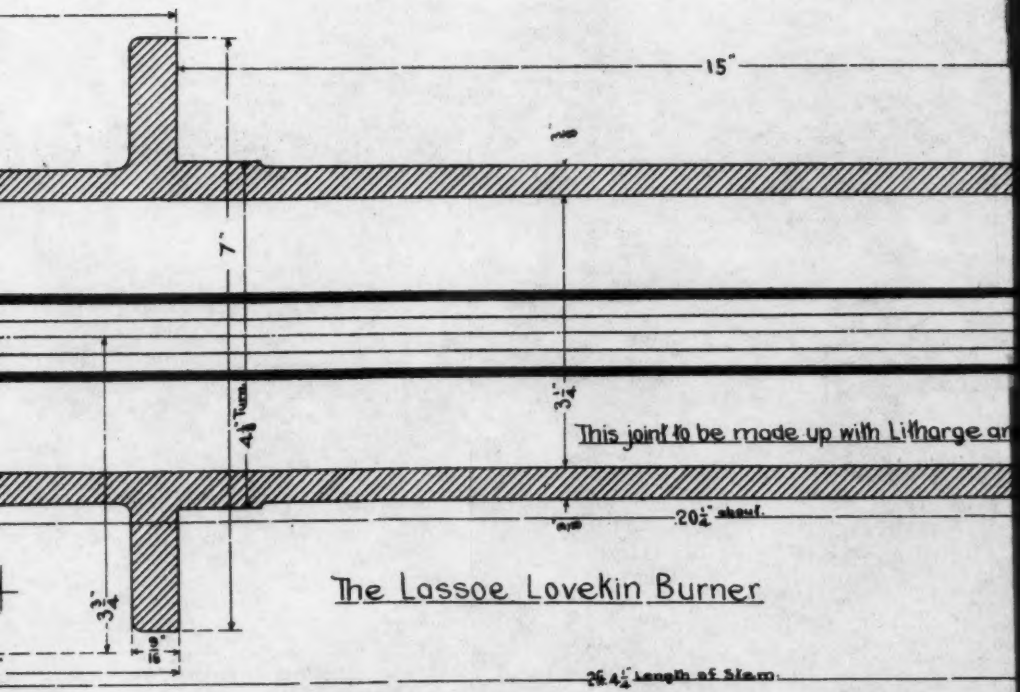

15"
7"
4⅛" Turn.
3¼"
This joint to be made up with Litharge an
20½" skeuf.
The Lassoe Lovekin Burner
26 4¼" Length of Stem.

Fig. 37.

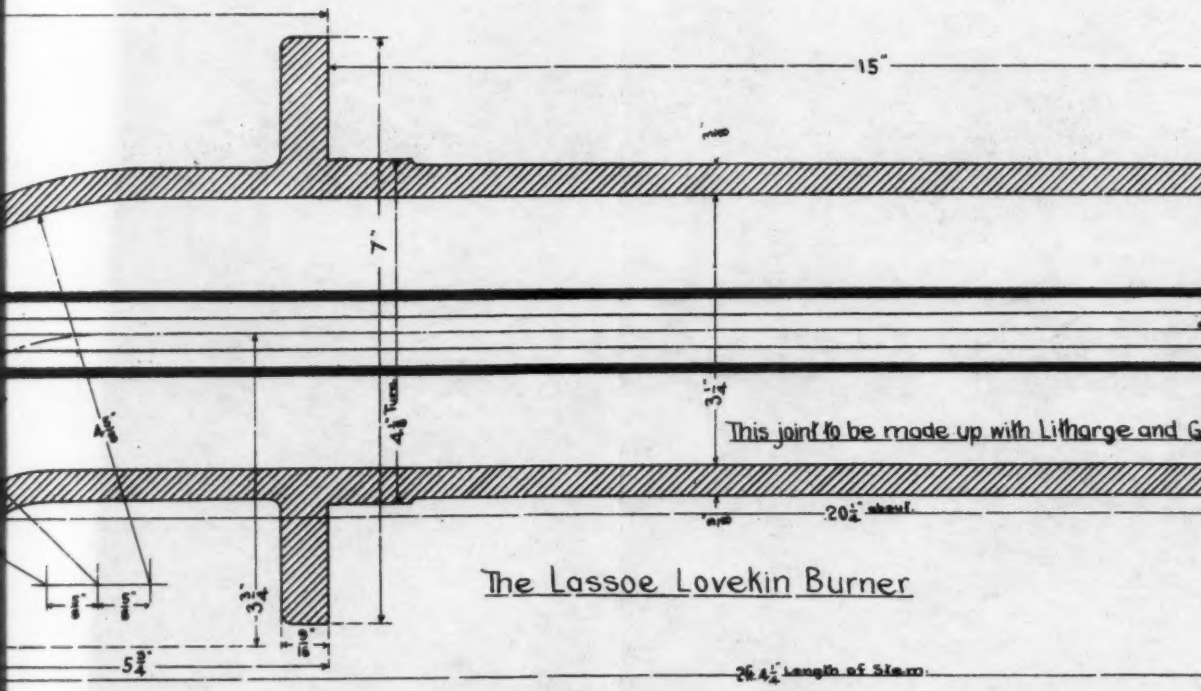
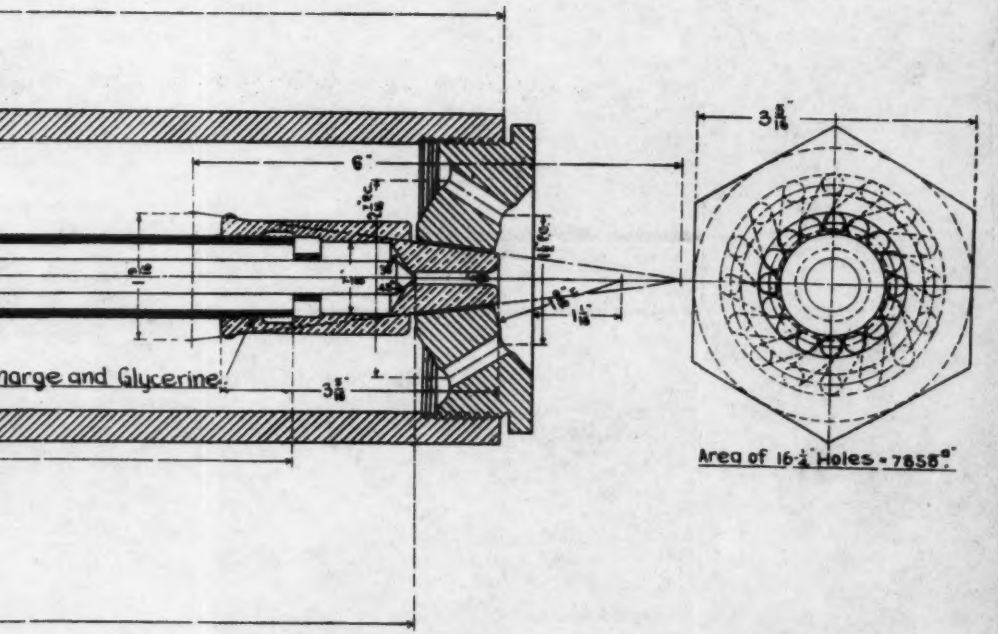

15"
7"
This joint to be made up with Litharge and G
20½" about
The Lassoe Lovekin Burner
26 4¼" Length of Steam

Fig. 37.


6"
3 5/16"
harge and Glycerine
3 5/16"
Area of 16 1" Holes = 7858"

air can be used as a spraying medium, air delivered under low pressure is preferred.

(*b*) The air necessary for supporting combustion is heated by means of the Howden system. A portion of this heated air is used for spraying purposes.

(*c*) The oil is heated so as to make it flow more readily through the pipe, and this heating of the fuel is effected by a steam coil fitted around the suction pipe of the oil pump.

(*d*) Special means have been provided to prevent any water that may enter the oil tanks from being pumped to the burners, a float arrangement having been installed whereby oil alone is pumped from the tanks.

(*e*) The brickwork installed in the furnace is of exceedingly simple character, the front end of the furnace being lined for about 2 feet, and a simple vertical lining against the back combustion wall being all the brickwork required.

(*f*) The main supply of fuel is carried in a bunker or expansion tank extending the full width of the ship, and for a distance of about 20 feet fore and aft carried from the bilge to the upper deck. There is a cofferdam both forward and aft of this oil bunker, and thus any leakage of oil can be quickly noted.

(*g*) There is a reserve of every important auxiliary, so that in case the impairment of one appliance occurs the reserve auxiliary can be immediately put in operation.

(*h*) When oil was first used in the Scotch boilers of the *Nebraskan* it was found that the smoke stack temperatures reached as high as 1,800 degrees Fahrenheit.

Retarders were then placed in the 3-inch tubes. The retarders now used have a convolution for each foot in length. The experience of this ship shows the exceedingly high velocity of the gases after complete combustion of oil fuel has been effected, and the imperative necessity of checking the flow of gases in all forms of boilers either by retarders or bafflers.

The whole design of the installation is of a character that represents excellent workmanship and careful attention to details. The heating of the air requisite for combustion, by the waste gases, undoubtedly increases the economical efficiency. There

is a clear and distinct recognition of the fact that crude oil is a very dangerous fuel where there is careless or inefficient installation, and that the dangers of such an installation can be reduced to a minimum where the plant has been designed by experienced and conscientious experts, and operated by intelligent and observing engineers. The importance of guarding against any mixture of oil and water is shown by the precautions that have been taken to prevent any leakage in all steam and oil joints.

The general features of construction and arrangement of double-bottom tanks for the carrying of oil and water are as shown in figure 38.

The general dimensions of the *Nebraskan* and its details are as follows:

CAPACITY OF HOLDS.

	Cubic feet.
Upper 'tween decks:	
Forward	38,570
Aft	33,510
'Tween decks:	
No. 1	15,335
No. 2	14,515
No. 3	13,180
No. 4	18,225
Holds:	
No. 1	29,890
No. 2	40,890
No. 3	22,556
No. 4	18,070
Refrigerators	23,489
Magazine	3,985
Total	272,215

GENERAL DIMENSIONS.

Length, feet	360
Beam (molded), feet	46
Depth, feet	34
Draught, feet	23
Two engines	Twin screw.
I.H.P.	3,000
Diameter of cylinders, inches	19, 31, 54
Stroke, inches	42
Two boilers, diameter, feet and inches	12- 3 by 16- 3
Steam pressure, pounds	200

Bunkers.	Cubic feet oil.	Tons coal.
Main bunker	24,460	525
Hatch trunk	620	14
Wing bunkers	.....	432
Trunk and saddle back	.....	18
Total	25,080	989

Oil, in gallons	187,598
Oil, in tons	641

DOUBLE-BOTTOM CAPACITY.

Inner bottom :	*Tons.*
No. 1	96
No. 2	196
No. 3	62
No. 4	48
No. 5	41
No. 6	86
No. 7	89
No. 8	35
Forepeak	139
After peak	84
Deep tanks (105–119)	178
Deep tanks (138–157)	148
Total	1,202

From the arrangement of the ship, as indicated in the longitudinal profile, it will be observed that the oil is stored in six separate compartments of the double bottom, and in the after peak and forward peak tanks, and in a large amidship-athwartship bunker. Under the engine and boiler compartment no oil is carried, but these compartments are reserved for the necessary supply of fresh water. Additional fresh-water tanks are installed just aft the engine room in side tanks located at the side of and above the refrigerator plant. There are also additional water tanks arranged in No. 4 hold between and at the sides of the shaft alley. These water tanks are sufficient to supply all the usual needs for fresh water. Any increase in the demand for fresh water can be made up by the evaporators.

The oil compartments in the double bottom are not directly contiguous to each other at the bulkhead subdivisions, and the necessary effect of a dividing cofferdam is obtained by the con-

struction of the athwartship bilge well. Here any collection of gas or oil leaking from the tanks can be detected, thus affording an additional element of security. The large amidship oil bunker rises to the upper 'tween decks, and is flanked on forward and after ends by cofferdams of one frame space in width, thus both ends of the bunker are readily accessible, and leaks of gas or oil can be checked in their incipiency. This large bunker is also provided with the usual division bulkheads or swash plates to prevent violent pitching of the oil during the rolling of the vessel. The expansion of the oil in this tank is taken care of by the construction of an expansion trunk reaching to the bridge deck.

Fig. 39 shows the general arrangement of the furnace installation of the oil-fuel devices as fitted on the *Nebraskan*. It will be observed that the furnace is lined for its full length on the bottom while only for about half the distance on the top. There is a vertical brick lining to the back combustion wall to a distance just slightly higher than that of the height of the furnace.

BOILER DATA STEAMSHIP "NEBRASKAN" (TWO SINGLE-ENDED SCOTCH).

Diameter, feet and inches	16- 3
Length, feet and inches	11- 6
Tubes between tube plates, feet and inches	8- 3
4 furnaces, Morison:	
Large D, feet and inches	3- 7½
Small D, feet and inches	3- 3
3-inch tubes, common, 1 boiler, No. 12, B.W.G., number	196
stay, No. 3, B.W.G., 1 boiler, number	110
Grate length, feet	6
surface, 1 boiler, square feet	81
Tube surface, 1 boiler, square feet	2,527
Heating surface, 1 boiler, square feet	178.5
Total heating surface, square feet	2,998.5
Steam capacity, cubic feet	495
Area through tubes, square feet	15
H. S. ÷ G. S	37.
G. S. ÷ area through tubes	5.29
Shell plates, inches	1⅛
Front and back, inches	1 7/32
Tube plate, inch	5/8
Furnace thickness, inch	9/16

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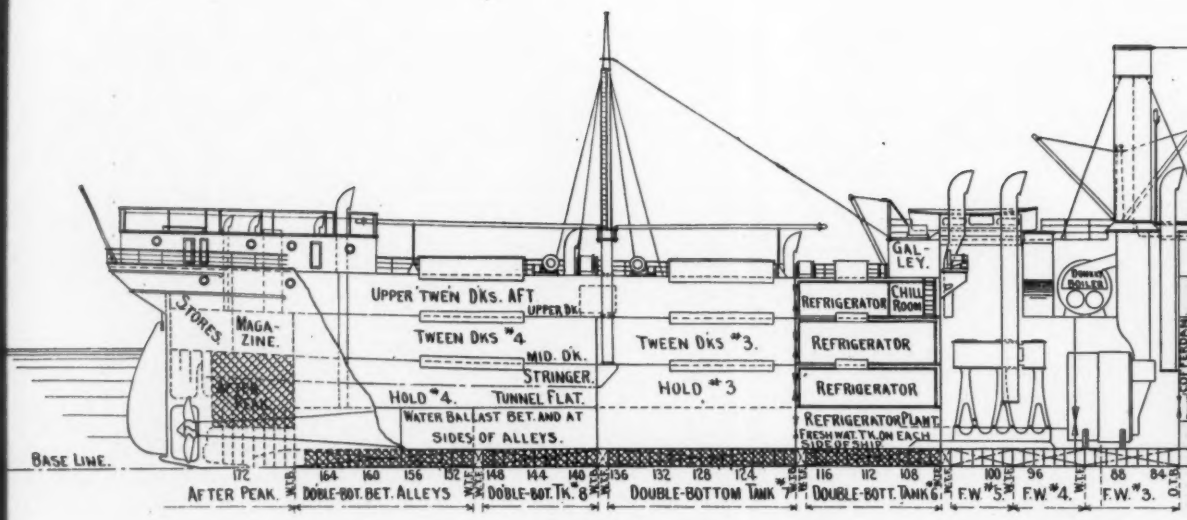
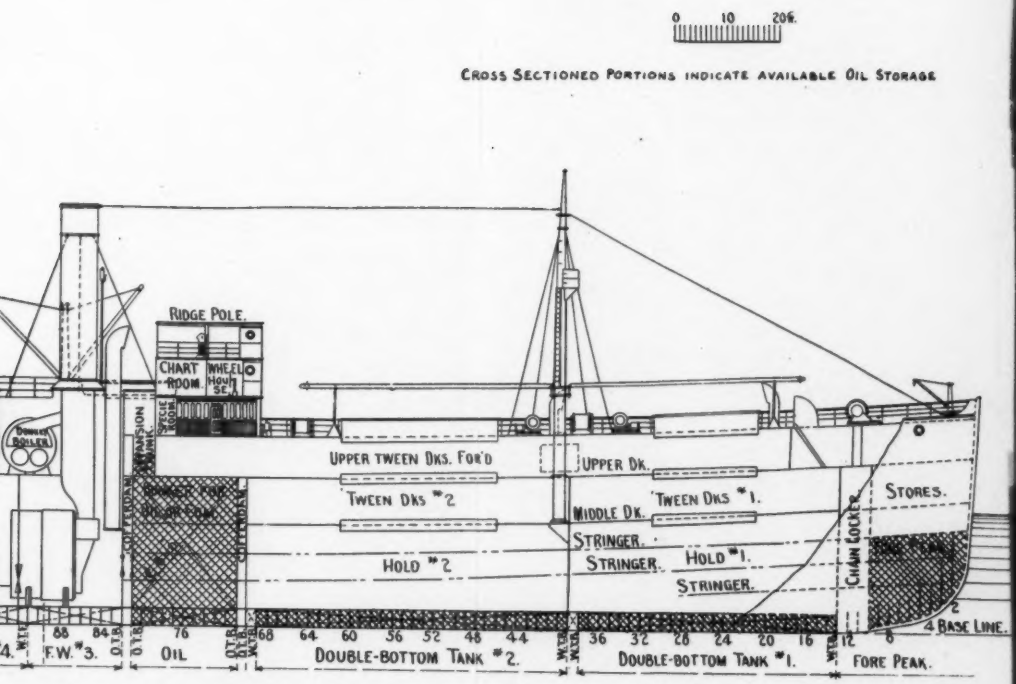
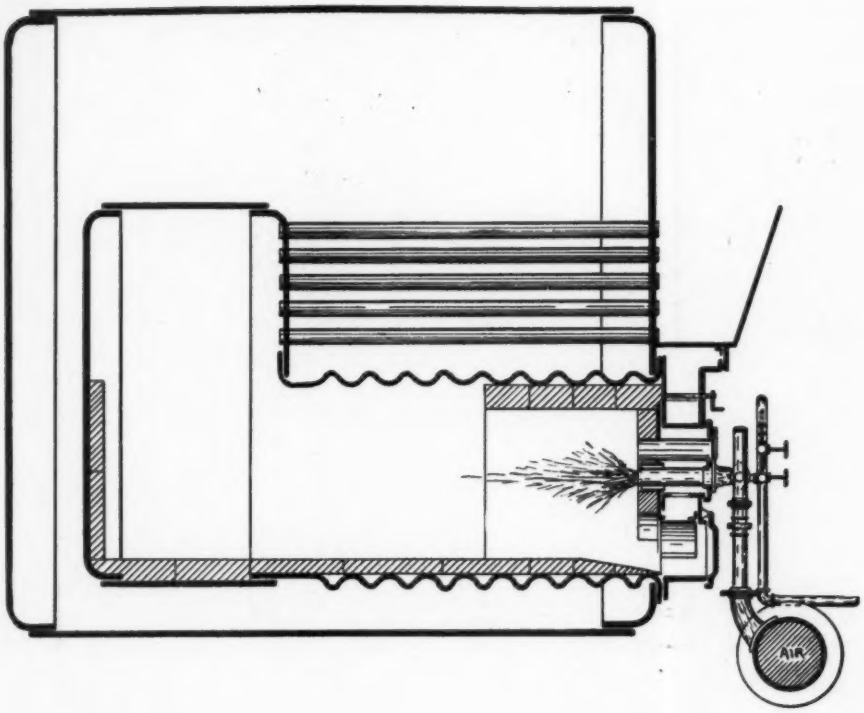
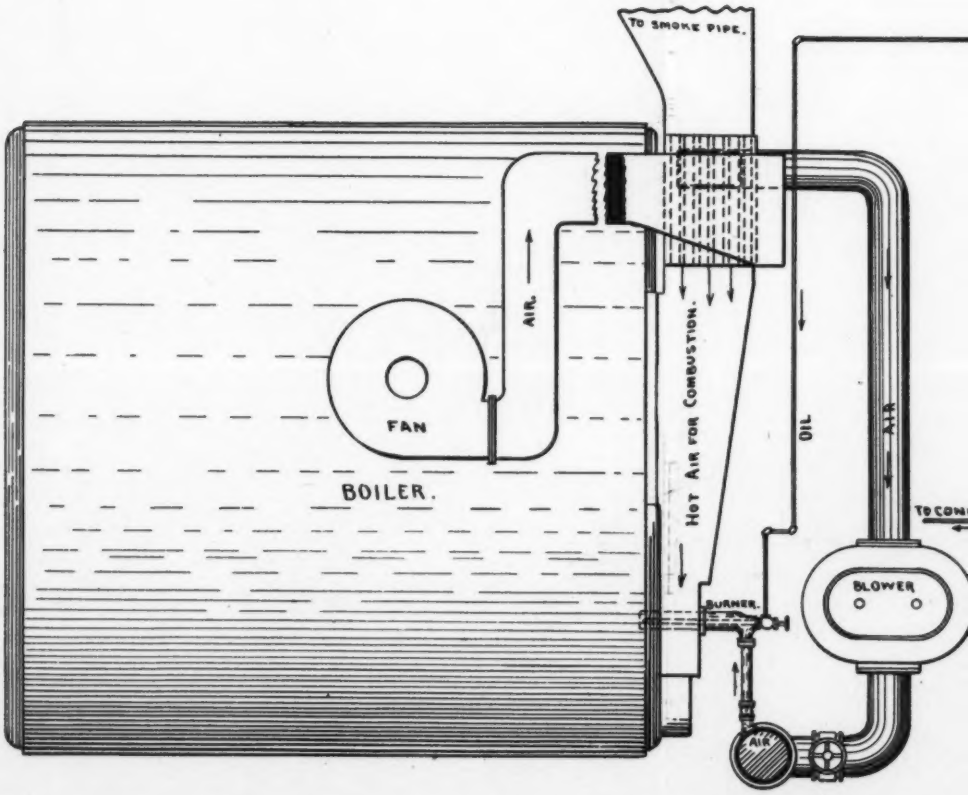


Fig. 38.—American Hawaiian Steamship Company "Nebrask

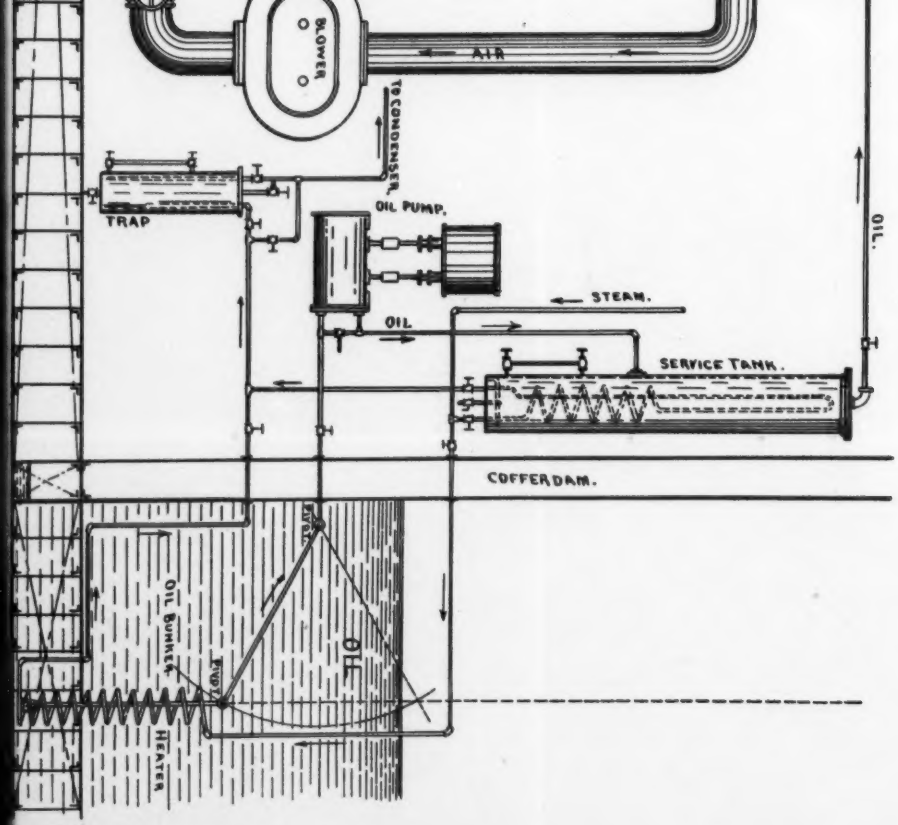


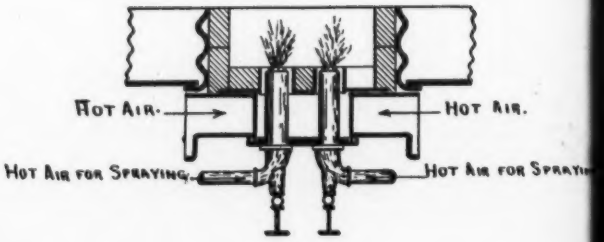
NY "NEBRASKAN". DISPOSITION OF FUEL-OIL BUNKERS.





DOUBLE BOTTOM: WATER BALLAST


BLOWER
AIR
TO CONDENSER.
TRAP
OIL PUMP.
OIL.
STEAM.
OIL
SERVICE TANK.
COFFERDAM.
OIL BURNER
STEAM
OIL
HEATER


HOT AIR.
HOT AIR.
HOT AIR FOR SPRAYING.

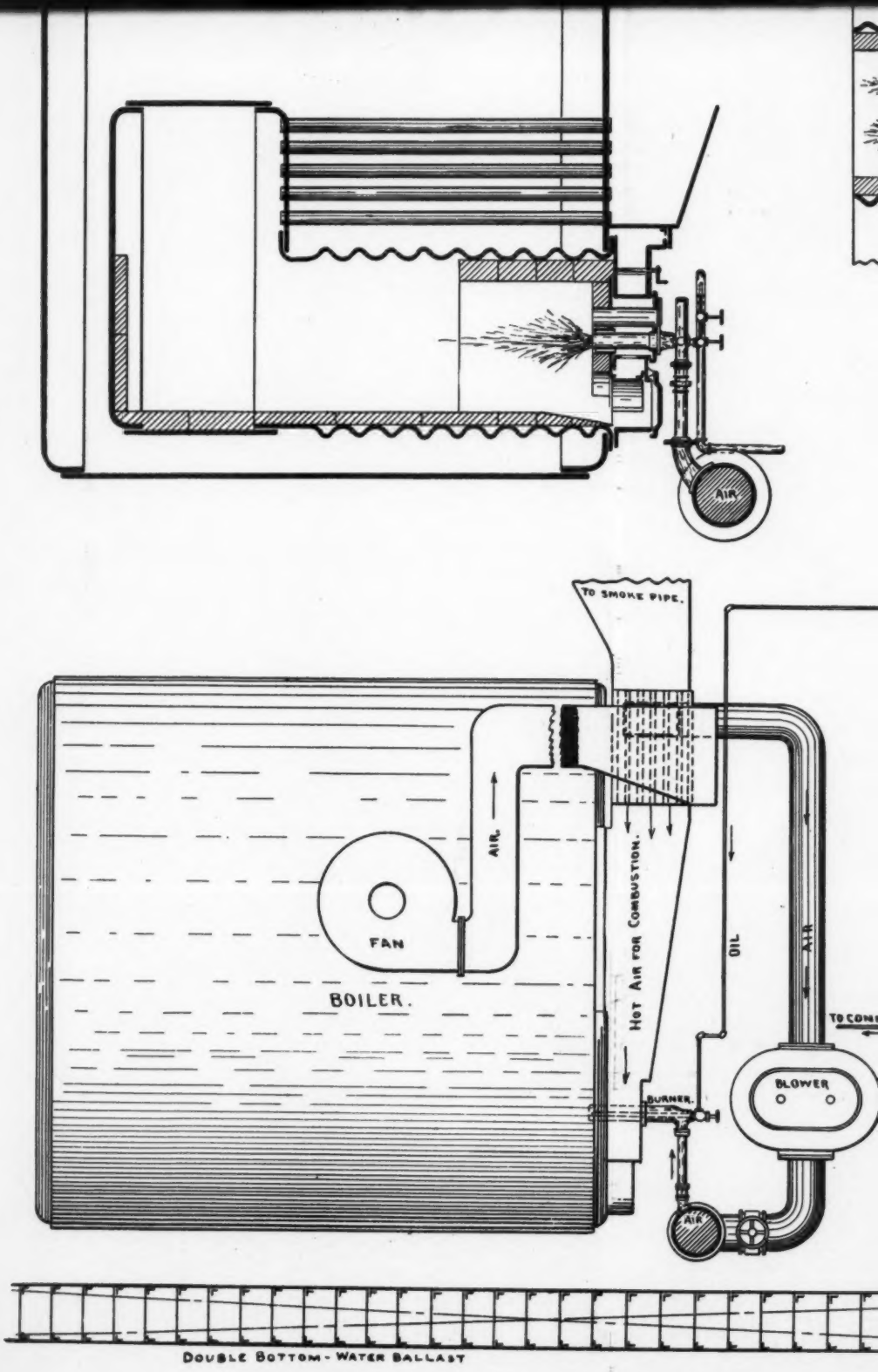
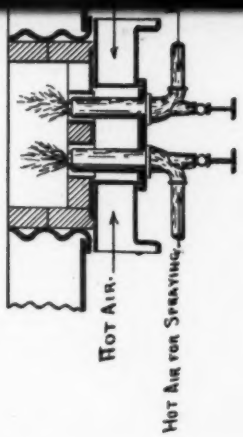
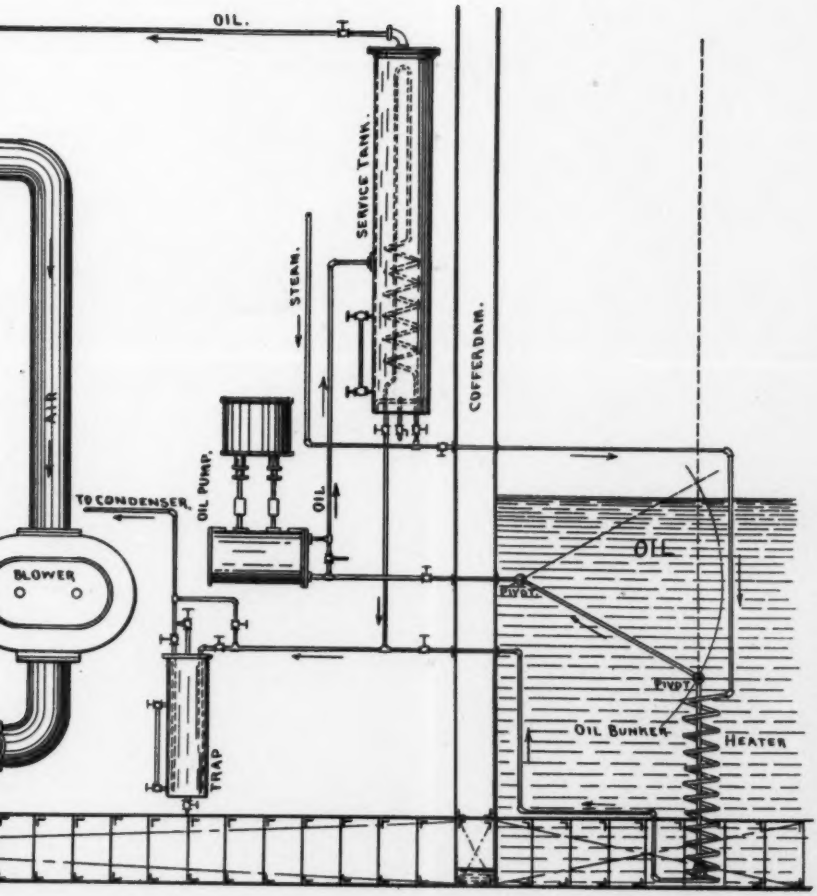


Fig. 39.—American Hawaiian Line S. S. "Nebraskan". General Arr





GENERAL ARRANGEMENT OF OIL-BURNING INSTALLATION.

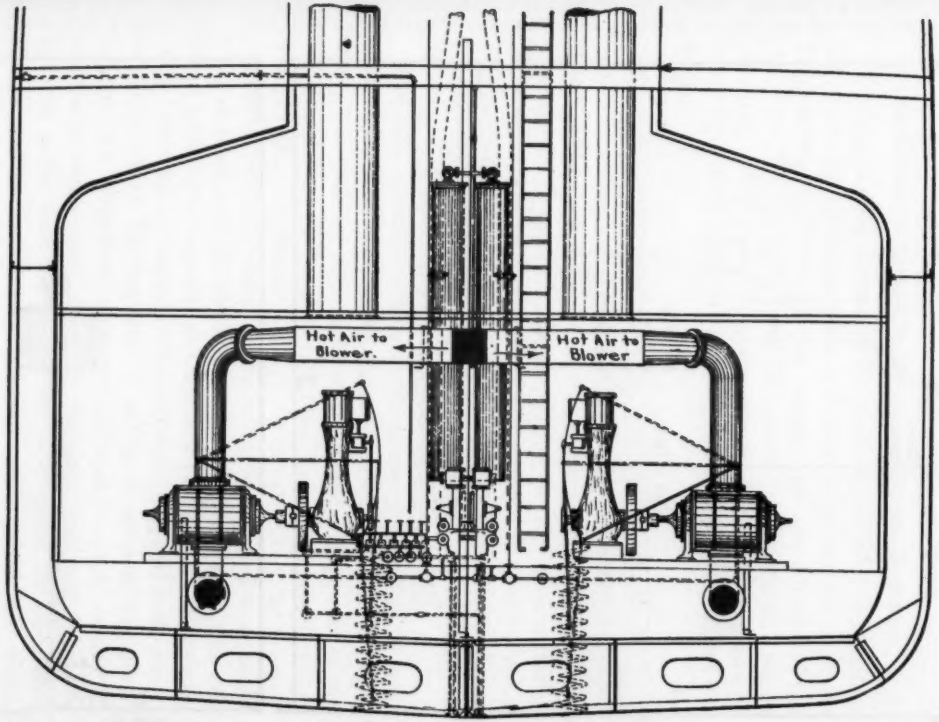


Fig. 40.—THWARTSHIP SECTION THROUGH FURNACE ROOM, AMERICAN HAWAIIAN LINE S. S. "NEBRASKAN".

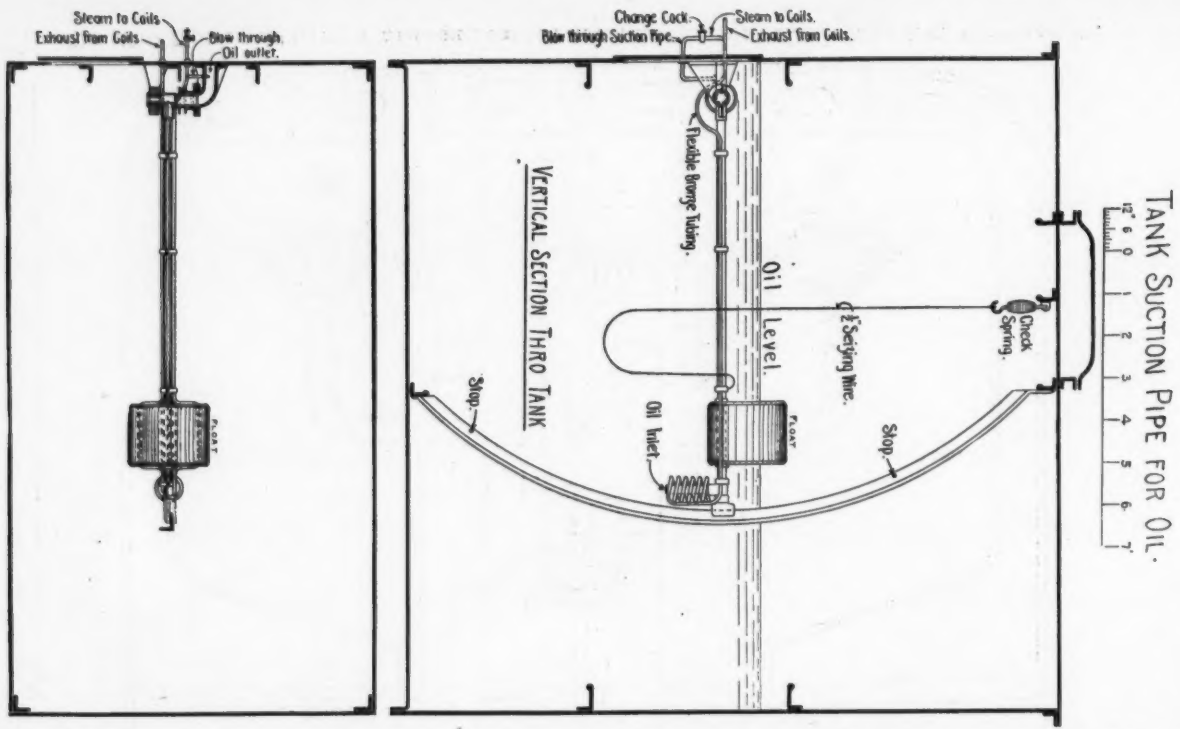


Fig. 97.—Device for Taking Oil near Top of Variable Oil Surface; Instead of Taking Oil out of Fixed Outlet at Tank Bottom, with Resulting Possibility of Obtaining Water instead of Oil.

SIMILARITY OF CONDITIONS ATTENDING THE OIL-FUEL INSTALLATIONS FOR LOCOMOTIVE AND TORPEDO-BOAT WORK.

OBSERVATIONS OF THE BOARD AT THE HOOSAC TUNNELL.

The progressive increase in the number of oil-fuel installations for locomotive work particularly interested the Bureau of Steam Engineering, and through the courtesy of the officials of the Atchison, Topeka and Santa Fe, and of the Boston and Maine railroads, reliable and valuable data and important drawings concerning such installations were placed at the disposal of the Board.

* * * *

For special information in regard to the Hoosac Tunnel oil-fuel locomotives, as well as to other railroad installations, the Board is indebted to W. D. Hoffman, the fuel-oil expert of the Standard Oil Company. This expert has likewise been in charge of the work of installing liquid-fuel appliances on locomotives in Florida, as well as in other sections of the country, and the Board is under obligations to him for valuable suggestions in regard to effecting such installations on torpedo boats.

The most important change made in the Hoosac Tunnel locomotives for burning oil instead of coal was in the fire-box arrangement. The drawing of the fire box shows the arrangement of the burner and the fire-brick arch. [See plate No. 1, page 236, JOURNAL, Vol. XV, No. 1, February, 1903.] The burner enters the fire box just beneath the rear water leg and is inclined upward at an angle of 15 degrees, so as to direct the flame under the arch. The ash pan is replaced by a special pan, which is bolted to the lower ring of the water leg, and supports the fire-brick lining and arch, as well as the dampers. The fire brick is laid up in alternate courses of headers and stretchers, although in front a single course of stretchers may be used, except in the center wall, which braces the arch to the tube sheet. At the back end of the box a tie wall is built in, resting on angle irons, to stay the side walls. The damper is arranged so that it may be entirely closed for holding the steam pressure with a light fire.

The burner is of ingenious construction, consisting of a double burner—a narrow one on top and a wide one below. Both are

flat, or slot, burners, with the steam orifice arranged behind that for the oil, so as to blow steam through the stream of oil. A burner of this type, with properly proportioned steam slot and opening for the atomized spray, is capable of efficiently burning 150 gallons of oil per hour. A similar burner for locomotive work is shown [plate No. 5, page 246, JOURNAL, Vol. XV, No. 1, February, 1903], this burner being arranged for insertion in the fire door instead of at the mud ring. A large air opening is provided near the burner, to admit air for initial combustion, while the damper at the rear of the box furnishes what more is necessary. This burner has given satisfaction, having never become stopped up. With the small burner it is possible to adjust the fire very low for the purpose of holding steam during long waits or delays, while with both burners a capacity beyond any possible requirement is available.

The arrangement of the steam and oil piping for the burner is very simple. Oil is fed directly from the tender tank to the burners under 5 to 10 pounds air pressure (from brake reservoir), and the steam is likewise controlled by the throttle valves, all of which valves have their handles located conveniently in the cab. The piping is, as shown, conveniently fitted with brass unions, to facilitate taking the burner down, and bends are used in place of fittings wherever possible. A steam connection is run to the tender, through a reducing valve, to supply the tank heater, and another steam connection is arranged outside the cab to supply the steam oil pump at the storage station when filling the tender tank.

In regard to the similarity of conditions and requirements of oil-fuel installations for locomotive and torpedo-boat work, the following advantages are possible in both cases:

(*a*) Economy of space reserved for carrying fuel.

(*b*) Ease in filling tanks.

(*c*) Rapidity of time in meeting a varying load on boiler.

(*d*) Ability to force boiler to extreme duty in case of emergency.

(*e*) Absence of smoke under light normal working conditions.

(*f*) Short height of stack.

(*g*) Superior personnel available for the operation of the burners.

(*h*) Ability to secure and maintain higher speed with oil fuel than with coal.

The accompanying photograph [See page 231, JOURNAL, Vol. XV, No. 1, February, 1903] showing one of the Boston and Maine engines "double-heading" just before entering the Hoosac tunnel, with oil and coal-burning locomotives, will tell of the possibility of torpedo boats at reduced speed burning oil without smoke issuing from their stacks. It must be understood, however, that the smokeless burning of oil fuel in a torpedo boat can at present be effected only when there is a limited consumption of fuel. The efficiency of such boats, however, may be vastly increased when improved baffling is secured, and it is hoped that the smokeless burning of oil may be eventually obtained even with a marked increase in fuel consumption.

The Board considers that the eradication or mitigation of the smoke nuisance in torpedo boats is intimately connected with the question of baffling, and the commanders of the various torpedo-boat flotillas could render the Bureau an inestimable service by making experiments with various forms of baffling. In the small or bent-tube type of water-tube boilers the most important problem now confronting experts is a systematic arrangement of baffling whereby combustion can be effected within the tubes instead of within the smoke stack. A special design of baffling will have to be arranged for each distinct type of water-tube boiler.

* * * *

The comparative study of oil-fuel installations for torpedo boats in connection with the development of locomotive oil burning is worthy of special and further investigation by the Department, and the good of the service would be subserved by detailing some of the commanders of the torpedo boats to special temporary duty in observing and reporting upon the work performed by the oil-burning locomotives of the Atchison, Topeka and Santa Fe and Southern Pacific Railroad systems.

MECHANICS OF COMBUSTION AS SPECIALLY RELATING TO USING LIQUID FUEL.

While the theory of combustion is well understood by all having a knowledge of the elementary principles of chemistry, there are practical considerations that enter into the matter of burning both oil and coal as a fuel, and therefore the economical consumption of fuel in large quantities can only be effected in boiler or furnace installations which have been designed by technically trained experts possessing a knowledge of what well may be termed the practical mechanics of combustion. Considering also the widespread and special interest now taken in the oil-fuel problem and the fact that radically different systems of oil-fuel installations are being projected, it is deemed specially important to consider the question of how the combustion of oil may be best obtained.

Hundreds of oil burners have been designed which, viewed from a chemical and theoretical standpoint, should have operated efficiently; and yet when such appliances were subjected to actual tests the devices proved unsatisfactory. There are, therefore, practical conditions as well as chemical principles that must be considered in the solution of the liquid-fuel problem, and the Board thus regards the mechanical features of the oil-fuel combustion question as a subject deserving of special study and investigation.

Everyone is aware of the fact that with a charcoal or coke fire it is possible to maintain very intense combustion within a comparatively small space and with very little smoke. This sort of fire was known to the smelters of the bronze age, and it is still used in blast-furnace and other operations where great concentration is required.

The explanation lies in the fact that the fuel is solid, even at the highest temperature. The solid particles in the smoke are probably particles of ash, but whether they are ash or unconsumed carbon, they are exceedingly small, as shown by the bright blue color of the smoke. As a result of this solidity no carbon can leave the bed of hot coals except as a constituent of CO or of CO_2. In either case the combustion will be free of soot

or smoke, since both gases are colorless and transparent. If the carbon goes up the stack as a constituent of CO it carries with it two-thirds of the heat that it was primarily capable of yielding up, and it is only with respect to the possible formation of CO instead of CO_2 that a charcoal fire fails to give perfect results. Were it not for this possibility there would be no reason why a charcoal fire should need more space than is sufficient to contain the fuel itself. The obvious way to prevent the formation of CO is to force a larger quantity of air through the bed of coals, but this alone is insufficient. Experience shows that even when the amount of oxygen passing through the bed of coals is twice that requisite for the complete combustion of the carbon, there is still some of the carbon that leaves the furnace in a partly burned condition. The only way in which this carbon can be completely burned is by subsequent diffusion of the gases whereby each molecule of CO sooner or later meets with an atom of free oxygen and so becomes CO_2. But this diffusion requires time; and as the gases are being constantly cooled as they are carried along, it may happen that they will be cooled below the ignition temperature before union takes place. So that even in a charcoal fire the need for appreciable combustion space is obvious.

Complete combustion requires that for every atom of carbon and for every two atoms of hydrogen there shall be at least one atom of oxygen brought in close proximity and then and there subjected to a temperature sufficient for ignition. In other words, there must be a thorough mixture and then ignition. It is doubtful if a mere mechanical mixture, however complete, could ever be perfect enough to bring about the desired result. This is well illustrated by contrasting the smoky combustion of black gunpowder, where we have a mechanical mixture, with the combustion of the so-called smokeless powders, in which the mixture is so thorough and minute that similar proportions of oxygen, carbon and hydrogen occur in each separate molecule.

In all ordinary cases of combustion, however, where we draw our supply of oxygen from the atmosphere, it is only by virtue of the property of diffusion that a sufficiently intimate mixture is

attained. As to the real nature of diffusion, it is known that at ordinary temperatures the particles of oxygen in the air are moving about in every conceivable direction at velocities averaging over 1,600 feet per second. Any one atom, however, moves only an inappreciable distance before being arrested by collision with another atom. So that although the average velocity of the atoms is probably equal to that of a rifle ball, it still takes an appreciable time for a particle to travel even a moderate distance. It is this time element that constitutes the great stumbling block when the attempt is made to burn a large amount of combustible in a small space.

As before noted, the reason why intense combustion is easily attained with a charcoal fire is that the fuel is solid at the temperature of ignition. Being solid, it can present a large surface for the oxygen to act upon, and an atom cannot break away and go up the chimney without at first being united with at least one atom of oxygen.

In the combustion of hydrocarbons, on the other hand, we have the following conditions: The fuel is already on its way to the chimney before it is even partially burned. The first effect of the heat is to dissociate the carbon from the hydrogen. Whether or not the latter unites with the oxygen does not affect the soot or smoke question, since the constituents and also the products of combustion of hydrogen are alike transparent, colorless gases. But in any case the carbon, left alone in the form of an impalpable dust, is much less favorably circumstanced than that in a charcoal fire. If it were attached to a hot coal, as in the charcoal fire, so as to be capable of receiving a blast of air, its combustion would be easily accomplished. But instead of this, it is carried along by the current of gases, and unless it is given plenty of time before being cooled it will be left alone as a particle of soot.

An examination of the nature of flaming leads to similar conclusions. The luminous part of a flame is caused by the white-hot particles of carbon. These particles have been robbed of the hydrogen with which they were formerly associated, and they have not yet met the oxygen necessary for complete com-

bustion. This process of finding, or of being found by, the oxygen requires time, and if perchance the temperature falls below that of ignition before the process is completed, the carbon will be deposited as soot or else go on up the stack as smoke along with the excess of oxygen with which it should have been united. Thus an unmistakable symbol of the conditions that are necessary in order to burn a large amount of combustible in a small space is a short flame.

The circumstances which conduce to shortness of flame are:

First. Pure carbon fuel, because the fuel cannot leave the grate or furnace until it is burned to CO at least. In any case it cannot deposit soot, since CO when cooled is a transparent gas.

Second. Intimate initial mixture of oxygen with the fuel, since the more intimate the mechanical mixture the less time will it take the gases by the process of diffusion to become perfectly mixed.

Third. Initial heating of the air, since the rate of diffusion increases with temperature.

Fourth. Large surface of fuel presented for impact of the oxygen.

The desirability of supplying a combustion chamber whose volume is at least equal to the volume of the flames seems obvious. In this connection the fact should not be overlooked that a slight increase in the volume of the combustion space acts in two ways to improve the quality of the combustion. One way, that having to do with the greater time permitted for diffusion, has already been touched upon; but apart from that there are influences at work in consequence of which an increase in the volume of the combustion space actually diminishes the volume of the flames. This is because the temperature of the larger space is higher, and the higher temperature hastens the process of diffusion.

During the process of diffusion heat is being liberated at all points throughout the combustion space. Hence all parts of the space are being traversed by heat rays emanating from every other part of the combustion chamber. It is readily seen that

the temperature within this space must, under these conditions, increase with the volume to an extent limited only by the transparency to radiant heat, and by the temperature of dissociation at which, necessarily, heat ceases to be liberated. Since the transparency of the combustion space is diminished by the presence of solid carbon (for whether black or incandescent it is in any case opaque), it follows that the increase of temperature with a given increase of volume will be less in a space filled with luminous flame than in one filled with burning hydrogen or CO.

This question of the proper size of the combustion space is further complicated by the presence and condition of the solid walls of the furnace, whether, for instance, they are themselves incandescent or merely black absorbers of heat. There seems no reasonable doubt, however, that incandescent walls will hasten diffusion and hence shorten flame.

Where it is possible for the diffusion to be completed before combustion begins, as in the Bunsen gas burner, the difficulties naturally disappear and there is readily attained a very short flame which, moreover, is incapable of depositing soot even on a cold object.

In the case of a liquid fuel which is incapable of vaporization the diffusion and ignition must occur simultaneously. With such a fuel there is bound to be considerable flaming. Another difficulty, and one from which all solid fuels are free, arises with this sort of fuel from the action of capillarity or surface tension. Thus, no matter how finely the liquid is pulverized, each tiny drop assumes a spherical shape and so presents the least possible surface for the impact of oxygen atoms.

From what has been said it seems clear that a liquid fuel such as crude petroleum requires an ample combustion space, more, indeed, than does almost any other sort of combustible material.

The relative dimensions—length, breadth and depth—of the combustion space are of minor importance. The primary requisite is volume, and that alone, provided all parts of it are traversed by the same quantity of gas in a given time; in other words, provided the gases are not short-circuited through or across some parts of the space to the neglect of others. Thus, if a current of

gas flows through a cubic foot of space at the rate of 1 cubic foot per second, each particle of gas will spend one second within the space, regardless of whether the space is long and narrow or short and wide. In a long and narrow space there is less chance of the gases taking a short cut, and herein lies the sole utility of introducing baffles in the combustion space. Indeed, there is a strong objection to their introduction arising from the fact that the narrower the passage the greater will be the velocity of flow and the greater the distance to be traversed. Since the resistance that the draft pressure must overcome is proportional to the square of velocity of flow and to the length of the passage, it follows that for a given volume of combustion space the draft resistance will be proportional to the cube of its length. The advantages are, therefore, in favor of the combustion space of large cross section and short in the direction of the flow of the gases.

As to the difficulty arising from the tendency of the gases to follow the path of least resistance and to flow, for instance, with too great velocity at the center of the space and too little at the sides, that can always be checked by means of retarders placed so as to equalize the velocity over the cross section of the current. The difficulty, therefore, reduces itself to the mere trouble of finding out where to place the retarders, and this is obviously a question to be settled by experiment. What is true in this matter of the combustion space is also largely true of the tube space. The process of diffusion, so important to combustion, continues after the combustion is complete, and must have a good deal to do with the rate at which heat is abstracted from the gases by the heating surfaces. As affecting the necessary amount of draft pressure, a tube space short in the direction of flow of the gases and of large cross-sectional area is better than one of small area and long in the direction of flow; but on account of the lesser velocity of flow through the short space the gases within it will be less thoroughly mixed by eddying, and the importance of arranging the heating surfaces so as to permeate all parts of the space will be increased.

A primary requisite for the successful burning of a non-volatile liquid fuel is the exposure of the fuel to the heat of the furnace in such a form that it presents the largest possible surface for the impact of the atoms of oxygen. From the principles of capillary action it is possible to establish a standard by which to judge of the efficiency of the various methods for increasing the free surface of the oil.

Oil in bulk has practically no surface. When broken up into fine drops the surface is the aggregate surface of all of the drops. The smaller the drops of oil the more perfect the spheres. Thus drops of oil one one-thousandth of an inch in diameter are known to assume the spherical form with a rigidity comparable to that of a steel ball 1 inch in diameter. The work necessarily performed by the atomizing agent is simply the work of stretching the surface.

Petroleum whose density is 0.92 has a bulk of 30 cubic inches per pound. When broken up into spherical drops the surface of a pound of oil is $180 \div d$ square inches, d being the diameter of the drops expressed as a fraction of an inch. The work required to stretch the surface of petroleum is 0.0000151 foot-pound per square inch. From these facts we can compute the work done against surface tension in forming spray. This work is $0.00272 \div d$ foot-pounds per pound of oil. Thus for drops 0.0001 inch in diameter the work is 27.2 foot-pounds per pound of oil. There is no known method whereby, even in theory, oil can be sprayed with such a high degree of efficiency as that indicated above.

The only obvious way of stretching the surface of a liquid which, like petroleum, is incapable of being drawn into a thin film is by opposing force to change the momentum, and this necessitates imparting to each particle a velocity, and hence a kinetic energy.

The diameter of a gravity drop of oil (a drop which is broken off from a larger mass by the force of the weight of the drop itself) is about 0.15 inch. Starting from this datum we can derive an expression connecting the diameter of the drop with, for example, the diameter and the number of revolutions of a circular

disk from the periphery of which the drops are thrown off by the action of centrifugal force. Such an expression is

$$n^2Dd = 10{,}570,$$

where n = revolutions per minute,
D = diameterof disk in inches,
d = diameter of drop in inches.

The drops are, of course, thrown off with a velocity equal to the peripheral velocity of the disk. The kinetic energy represented by this velocity for petroleum, having the assumed density of 0.92, will be $0.00311\,\frac{D}{d}$ foot-pound per pound of oil.

This kinetic energy added to the energy required to stretch the surface of the oil gives us $\frac{0.00272 + 0.00311\,D}{d}$ foot-pound per pound of oil as the total energy required to spray the oil by this method. The kinetic energy is 1.14 D times the energy required to overcome the surface tension. To illustrate the above, suppose the drops are 0.0001 inch in diameter and the disk is 8 inches in diameter. The work of stretching the surface will then be 27.2 foot-pounds, and the kinetic energy will be 248.8 foot-pounds, making a total of 276 foot-pounds per pound of oil. Contrast this with the results attained with a steam jet.

When the oil is sprayed by a steam jet one-half pound of steam per pound of oil, or 5 per cent., of all the steam generated (evaporation 10 pounds of steam per pound of oil) is considered fairly economical. But in a moderately economical steam engine—*i. e.*, one giving a horsepower for 34½ pounds of steam per hour—one-half pound of steam yields 28,700 foot-pounds, which, at 252 foot-pounds per pound of oil, is capable of spraying 104 pounds of oil into drops 0.0001 inch in diameter. The steam jet is therefore only about 1 per cent. as efficient as is theoretically possible.

In making this comparison, we have of course assumed that the steam jet also produces drops 0.0001 inch in diameter. More likely the steam jet produces drops of various diameters. Some idea of their probable size may be formed from the following dimensions:

0.00000045 inch, thickness of black spot in soap bubble.
.0000845 inch, thickest red of soap-bubble film.
.0001667 inch, } diameter of drops in cloud of exhaust steam
.0002 inch, } from low-pressure engine.
.00897 inch, } diameter of drops in rain cloud just about to
.0222 inch, } fall.

The development of a simple mechanical burner ought therefore to be not only possible but probable. For marine work particularly such a burner would possess advantages over any appliance that required air or steam for effecting atomization of the oil fuel.

A study of the liquid-fuel problem from the standpoint of the practical or mechanical rather than the theoretical or chemical feature of combustion would therefore show that when an assured and reasonably cheap supply of such fuel can be obtained, and when steam generators are designed for burning oil exclusively, it will be essential for the efficient and forced burning of such fuel to provide boilers of greater volume than now constructed for designated horsepowers.

The resulting gain from the installation of naval boilers of greater volume than now permitted for designated horsepowers (even though such boilers would require more weight and space than now allowed for such horsepowers) would subserve naval interests and be manifest in the higher efficiency, increased capacity and in greater endurance of the boiler—the lungs of the vessel.

Where there are no limitations as to space, weight or height, as in land boilers, the increase in volume could be best secured, in the case of fire-tube boilers, by lengthening the tubes and furnaces and by enlarging the combustion chambers.

In the case of marine installations, and particularly so for naval purposes, the enlargement in volume could be best secured by giving the boilers greater height. In connection with this matter it may be incidentally stated that heretofore in naval construction the installation of a protective deck on gunboats and protected cruisers has limited the height of naval boilers. Now

that the usefulness of a protective deck in other than armored cruisers and battleships has been seriously questioned, it would appear as if the height limitation of boilers installed in naval ships of moderate displacement should not be so severe. In the case of the armored cruiser and battleship, the gain in efficiency and endurance that would be obtained from increasing the height of boilers fully warrants the designing in those vessels of a higher arched protective deck.

MECHANICAL BURNERS.

For marine purposes it has been desired that burners should be installed capable of effecting vaporization of oil without the aid of any intermediary of steam or compressed air. The direct use of steam entails a corresponding loss of fresh water, which in the case of ships undertaking long voyages means considerable financial loss, especially if an extra amount of fresh water has to be carried in tanks or double bottoms, or has to be made up by the expensive distilling and condensing operations of the evaporator. In stationary and land practice this loss of fresh water may be of no serious consequence, but for marine purposes the use of steam as an atomizing agent means a further additional charge against the ship, whether the extra water used must be obtained by distillation or whether a dead weight of water must be carried in the double bottoms.

Where compressed air is used as a medium with which to effect spraying, although no direct loss in fresh water is involved, the introduction of air compressors encroaches upon the weight and space allowed for installation of machinery and requires considerable attention in the nature of upkeep and repairs. The character of the air compressors necessary to supply sufficient air for a number of marine boilers is such that the space occupied by them in an engine room or other compartments is considerable. The horsepower required to operate compressors is also quite an item, and to this extent involves an additional drain on the fuel.

Since the early days of oil burning, various plans have been proposed to effect vaporization by entirely mechanical means.

Early inventions contemplated the use of oil running over surfaces exposed to the action of flames and the burning taking place directly on the exposed surface of the oil. All such plans proved decidedly inefficient owing to the fact that the air supply could never be brought to the burning surfaces of oil in quantities sufficient to effect complete combustion; consequently all mechanical burners operating on that plan have been long since abandoned. The next field of invention that gave indication of success was to design burners in which the oil would be sprayed positively by mechanical action.

Mechanical action can be resorted to, for the purpose of spraying oil by two general methods: First, to force oil outward under considerable pressure from a properly formed orifice, by the action of a special pump; second, by whirling or flinging the oil outward from a rapidly revolving mass or burner head.

The Board recognized the fact that to conduct extensive tests of these two separate means of burning oil fuel would require a long range of experimentation, which the facilities of the Bureau would not permit. Tentative experiments were, however, conducted, and of sufficient extent to indicate a possibility for successful development of these burners.

* * * *

Of the mechanical spray burners it may be said that very few have achieved success. It is obviously very difficult to devise an apparatus which is capable of dividing into a fine spray a material so thick and viscid as fuel oil. As a step to the study of how mechanical spraying can be effected an examination could be made of certain forms of nozzles now used for water spraying or for lawn sprinklers. In these little devices we have a somewhat similar problem. It is desired to spray water by means of no other power than that resting in the pressure of the water itself. In the case of oil, as the fluid is far more viscous than water, it would seem that a greater pressure should be applied to the fluid in order to effect a corresponding breaking up of the oil into particles.

* * * *

The fluid passing through the orifice under the action of the heavy pressure has first imparted to it a rotary motion, caused by the introduction of spiral blades, which blades should be sufficiently near to the orifice so that the rotation of the oil will not be reduced by the action of the skin friction of the passages between the blades and the tip or orifice. The fluid, once passing the point of the orifice, then comes into collision with the various streams of fluid, and, together with the centrifugal action, the ensuing result is that the oil will be expanded or thrown off into the radiating lines. The pressure behind the fluid, the pitch of the guiding blades, the sharpness of the orifice edges and the form of the central cone are all important items, each of which has a relation to the final result. Burners designed on these lines can give and have given very fair results.

* * * *

Any burner operating on the mechanical principle requires, as a fundamental essential for its satisfactory operation, that the oil should always be supplied under considerable pressure, probably never less than 40 pounds to the square inch, and many plants are stated to be running under regular pressures as high as 150 pounds.

It is further essential that the air supply should always be brought to as high a temperature as possible, either by superheating, as in the Howden system, or by proper arrangement of the furnace passages whereby the air can be not only made to pass between heated linings, but can be brought to impinge on the newly formed jet or spray of oil in such manner that combustion can be immediately effected. The air necessary for combustion must be under control and regulation in order to conform to the quantity of oil being forced through the orifice. With a carefully adjusted heated air supply and properly regulated burners this mechanical method of spraying oil will undoubtedly give satisfactory results.

* * * *

In arranging the ordinary furnace of a marine boiler for the burning of liquid fuel the following important points have to be kept in view:

(*a*) With a single mechanical burner probably no more than a quantity of oil sufficient for about 80 I.H.P. per hour can be injected into the furnace (enlarging this burner would impair its good working), and this often renders it necessary to place two and sometimes three burners on each furnace to allow the full quantity of fuel necessary for the creation of the desired steam, to enter the furnaces, and ample room should thus be given on the furnace front, as well as in the furnace itself, to allow for these additional burners.

(*b*) The air necessary for combustion—about 200 cubic feet per pound of oil—has to be well heated before coming into contact with the particles of fuel, and this contact should be as intimate as possible to allow every particle of oil to be well surrounded by the hot inflowing air. Care should be taken to allow the fresh air from without a free access to the furnaces, and therefore the stokehold gratings on deck should be made large and in accordance with the quantity of air necessary for combustion.

(*c*) To maintain a proper contact between air and fuel the air flowing in should surround the injected oil on all sides in the furnace.

(*d*) The jet of oil fuel must spray freely into the furnace and burn there without touching any of the boiler parts or brickwork, as this would cause the formation of carbon.

(*e*) A good quantity of brickwork is necessary in the furnace, not only to act as a bridge to prevent the escape of the gases unburned through the funnel or as a protection for the back of combustion chamber, but also to allow the brickwork, after being heated, to act as a heat accumulator, thus constituting an aid in keeping the furnace at a high temperature.

(*f*) The opening of the fire bridge for the outflow of gases should be tried very accurately, as an opening too small or too large would produce a thick smoke. Experience with Borneo oil fuel showed 0.6 square foot of opening per burner to be about the required size.

To these the Experimental Board would certainly add the following:

(*g*) Careful filtration of oil is an essential. As the spraying

nozzle must have a fine aperture, any chip or particle of sand or dirt will easily clog it, therefore filters of wire gauze should be fitted of mesh at least one-half the diameter of orifice. It would also be found beneficial to use double strainers.

It is also important that the temperature of the fuel oil should be raised by some system of gentle heating in order to increase the fluidity of the oil, but it should be noted that this heating should not be carried much over 140 degrees Fahrenheit. Perfectly cold oils of certain fields are, at low temperatures, very viscous, and in fact so thick at temperatures below 40 degrees that many have the consistency of a tar rather than oil.

The sprayed oil fuel after leaving the nozzle of the mechanical burner should show an even light gray color as water vapor. The brown or dark line in the prayed oil proves that there is some obstruction in the burner, and the needle or nozzle should be instantly taken out and cleaned or replaced by a spare one. The construction of most of the mechanical burners makes this change an easy matter.

* * * *

CLASSIFICATION OF OIL BURNERS.

* * * *

A general examination of the patents taken out clearly showed that the important elementary principles governing the designs of every satisfactory oil burner are comparatively simple and few, and that the most efficient burner for any purpose is, in general, the simplest piece of mechanism, using the least amount of steam or air for atomizing purposes.

The various schemes for superheating the atomizing agent or for converting the oil into a gas before leaving the burner are of doubtful value. One has only to consider the amount of air requisite to secure complete combustion to realize the improbability of accomplishing this purpose within the burner itself. The development of the successful oil burner has thus been in the direction of cheapness and simplicity. Extended experiments, as well as careful research and calculation, have shown the imperative necessity of providing for proper sizes of orifices,

and thus, simple as the oil burners may appear to be, the best of them represent in their development years of extended study, investigation and practical experience.

The ordinary user of liquid fuel should avoid the purchase and installation of any type of burner whose capabilities are advertised as extending beyond atomizing and supplying the oil uniformly and continuously. No burner should be used which has not been designed and manufactured by firms who have had experience in the work. The experienced and successful manufacturers of oil-fuel appliances make but few claims for their special burners. These experts recognize the fact that it is good workmanship, high quality of material and extended experience in the general installation of oil-fuel appliances that are the determining factors in its successful use.

The actual form of the burner, independent of the general installation, will have but little influence in determining either the economical efficiency, the evaporative capacity or the uniform burning of liquid fuel. For some purposes the single form of "Y" burner, where the fuel enters through one branch and the spraying or atomizing medium enters through the other branch of the angle, might be found answerable. In every form of efficient burner, however, it is imperative that there be fitted valves of such design that a uniform and small supply of oil be admitted and that the pressure of the spraying medium be absolutely under control.

In selecting the desirable form of burner for practically any purpose the essentials demanded are: A design capable of easy installation and operation, and a form of construction that will permit the rapid examination and quick renewal of parts. From various causes it will be found practically impossible to prevent foreign substances occasionally choking the burners, even though the liquid fuel before reaching the burners is heated and made to pass through a series of strainers. Any form of burner which does not permit rapid examination and clearing out of all foreign substances is unfitted for marine use.

The Board found that there existed upon the part of every expert a tendency to install too few burners. As the clogging

of these burners will occasionally occur, the only means of subjecting the boilers to uniform conditions is to have an installation of reserve burners, so that the extra ones could be quickly thrown into use. When it is considered that the cost of installing a few extra burners is trifling, as compared with the total cost of an oil-fuel installation, there should be no hesitancy in providing a sufficient number of burners; for a reserve appliance may secure a more uniform evaporative efficiency, as well as a greater output, and will help overcome some of the serious objections that have been experienced in the use of liquid fuel.

One of the special advantages claimed for the use of liquid fuel, that the work of the fireroom force is not only lessened but made less onerous, will only be realized by an installation wherein there is a reserve of burners. All the burners should be so installed that their flame should point somewhere near the center of the furnace, and special care should be taken that the oil product is not injected directly upon a heating surface.

The following grouping or classification of burners shows how simple are the guiding principles of construction of the thousands of forms that have been patented:

Burners.—There are two methods of burning oil which are mentioned in this report, and which the Board considered it not advisable to investigate, for the reason that either of the methods required use of purified oil rather than crude oil or petroleum. One of these is the method of open pans, hearths, drips, cups, etc., while the other is a gas furnace in which oil is first reduced to gas and then burned.

The use of crude oil or petroleum in either of these arrangements of apparatus, while possible for a short length of time, is not satisfactory as a continuous working method of forming combustion, and therefore cannot be regarded as efficient or practical. The reason for this ineffectiveness is due to the fact that all crude oil contains a heavy, solid base, or hydrocarbon residuum. In the case of the Pennsylvania oils a heavy paraffin constitutes the base, while in the California oils the base consists of heavy asphalt. Oils of other localities have varying quantities of either or both bases. Any burner or method which de-

posits these heavy bases is sure to become clogged and choked. As the separation of the hydrocarbons from the bases often takes place at temperatures sometimes as low as 130 degrees, it is readily seen that any heating of oil in pipes, pans, retorts, etc., by the action of the flame, or by indirect radiation whereby this temperature is exceeded, is sure to produce a choking or clogging of the apparatus.

Although these heavy hydrocarbons are of themselves good combustibles, yet if not supplied with a sharp air current while in combustion full burning can not be effected, and a remaining hard, clinker-like coke is left behind, a substance difficult to remove except by outside mechanical interference. Any boilers or furnaces equipped with apparatus of this kind, the Board readily foresaw, would lead to difficulties and needless experimentation.

To classify properly the remaining types of burners into distinct groups it was deemed desirable that the multitudinous numbers and varieties of design should be arranged, either in accordance with some ruling form of construction or by reason of requirements of operation. After a careful analysis of various types it was observed that five general classes would cover practically all of the main features of construction, and from these five classes various modifications could be made.

These five classes of oil burners may be thus grouped:

I. Drooling burner.
II. Atomizer burner.
III. Chamber burner.
IV. Injector burner.
V. Projector burner.

These five classes are shown by diagram, Fig. 58, in which each burner is pared down to its very simplest elements of construction, leaving out all unnecessary features of manufacture or detail which might be regarded as merely accessory.

I. *Drooling Burner.*—The name selected for this burner, while perhaps unusual, best expresses its function as seen from the diagram; the oil simply oozes out, or properly "drools" out, at the orifice over and on to the steam jet. In this case the drool-

ing oil is simply carried away on a jet of flaring steam. The action is supposed to be as follows: As the steam issues forth it expands within the layer or film of oil which is being carried into the air of the fire box. It may be thought that this rather rough method of effecting vaporization would hardly be possible or satisfactory; yet as large numbers of these burners have been and are in actual use, they cannot be regarded as crude or unsatisfactory.

II. *The Atomizer Burner.*—In this burner the oil is brought through an orifice from which it is swept off by a brush of steam or air. It is, in short, a principle made use of in an ordinary cologne sprayer. This form of spraying or atomizing is a very old invention, and its capabilities for spraying into a fine mist have long been appreciated.

III. *Chamber Burner.*—In this burner the oil and steam are more or less mingled within the body of the burner and pass out from the tip or nozzle as a mixture, and then, owing to the expansion of the steam, the oil is rapidly broken into minute particles. Burners of this type are simple in construction and have been carried through a large range of design.

IV. *Injector Burner.*—Burners of this type are analogous to the injector often used for boiler feeding and similar purposes. Here the steam and oil rising, each through its own passage, mingle within cone-shaped passages, and as a mixture passes through a contracted nozzle, and then outward through a reversed flaring cone. Burners designed on these lines have the principle common to injectors in general, that they can draw or suck the oil to them and force the mixture of steam and oil outward at considerable velocity. Burners of this type have been in use for forty years or more on the railroads of Russia and have become with that nation what might be regarded as a standard type.

V. *Projector Burners.*—In burners of this type the oil is pumped to the oil orifice and from there is caught by a passing gust of steam and blown off. This might be regarded as a sub-classification of No. II, the atomizer burner, except for the fact that the brush of steam is located some distance from the oil orifice, and this sweeping brush of steam, as usually constructed, is arranged

to entrain a certain amount of air further to aid in spraying and in combustion.

STRUCTURAL FORMS OF THE DROOLING BURNER.

The tips of each of these burners in each class can be specially modified, and will be later on treated under the subject of the forms of orificial spraying.

These five basic classes of burners will develop mechanically into certain structural forms, which structural or mechanical forms can likewise be arranged in four or five consecutive and related groups. The methods by which the various constructions have been developed from each class can be shown in the following diagrams: These forms, in turn, may be subdivided into groups, due to changes in details or to further refinements. By changing the pressure of the atomizing medium or by some slight variation of construction a long or short flame may be produced, and such character of the flame may be of special advantage for particular purposes. For certain manufacturing purposes or for the melting of refractory metals the flame required may be quite different from that requisite for purposes of combustion, and therefore simple modifications in the form of the burner may be productive of far-reaching results.

As a possible study of the modifications of the drooling burner, reference is made to Fig. 64. The first sketch shows the basic form of the drooling burner. This subdivides into four special classes designated as A, B, C and D.

In form A is shown the drooling burner made in its simplest possible form, the upper view showing simply two drilled holes, the larger for oil and the smaller for steam, while the lower view shows two pipes in a double T elbow, the larger pipe being for oil and the smaller for steam. Burners have often been made in this exceedingly elementary form, and will give results without any further recourse to mechanism. For convenience, we will term this subdivision A, as "straight-shot burners," due to the fact that the flame formed will have considerable length.

In form B the basic section of the drooling burner is developed into a class which gives two long slots. In this form a large

number of burners have been constructed, and in another part of this report results of tests are given on the Santa Fe burner, which has been largely used on a railroad of that name. In this simple form of a box-shaped casting these burners have gained a wide use, especially for railroad work. The construction is of course crude, but the results from a practical standpoint have been quite satisfactory, due to the fact that there are no complicated parts, and it is almost impossible to choke up any of the openings even with quite a dirty oil. Where burners are required to use a very heavy oil or residuum, or even a tar, these burners will always operate. This form B, which, for convenience, has been termed the long-slot burner, can be developed into the additional form C, or a fantailed burner.

In form C there are two burners which can be devised. The first form, in which the fan-tailed effect spreads through but a small arc of a circle, and the second form, in which the fan-tailed effect is extended so as to cover the arc of the entire circle. The first form will cover a large amount of surface in a wide or square fire box, while with the second form the burner can be placed in the center of a grate and the flame will extend outward in the form of a continuous sheet and cover the entire fire box or grate area, such uses being desirable, for example, in the fire box of vertical boilers, such as fire engines, &c.

The last form or modification, or form D, can be developed from the basic section of this drooling burner by conceiving that the section is revolved around an axis parallel with the burner axis. By revolving the section around an axis on the steam side there will be derived a burner of the style shown in the upper part of the pair of form D, or by revolving the basic section around an axis near the oil side we get a form of burner shown as the lower one. Either of these two burners, while apparently very different in form from the basic section, yet are nothing more or less than a development of the original type. Burners of this style should probably only be used where very heavy consumption of oil is required. In heavy metallurgical operations, brick kilns, and where a large volume of flame is desired, such burners have a wide field of usefulness.

POSSIBLE MODIFICATIONS OF CLASS II ATOMIZER BURNERS.

These forms are as shown in figure 69. At the top is shown the basic form of the atomizer burner. Then, under form A, "straight-shot burners," are shown two modifications, one formed by round openings in a small cylindrical casting, while the other is formed of a double T elbow containing two pieces of pipe, one for oil and one for steam, the end of the oil pipe being hooked over, as shown. The latter construction will be at once recognized as the very earliest form of atomizer. Its simplicity and effectiveness as a spraying agent can hardly be questioned. A position of tips can also be arranged so that a certain amount of siphonage can be secured in the oil pipe, although this is a function not to be at all relied upon.

Form B shows the same basic section of atomizer expanded sideways to form the "long-slot burner." This style of burner is also made use of very largely in locomotive work on account of its great advantages of wide and open passages which do not readily clog up, and consequently need but little attention.

Form C shows two designs, also derivable from the previous form and the basic section, the upper of the two showing a fan-tailed effect through a portion of an arc of flame and the other a flame distributed around the whole circle—the latter style of probable service when placed in the center of grates of vertical boilers.

Form D, rose burners, shows the basic section revolved about an axis either on the oil side or the steam side. In the first case, while securing a satisfactory atomization of oil, there would be obtained the effect of more or less of a straight-shot burner, while the latter form of rose burner would afford more of a flaring effect.

POSSIBLE MODIFICATIONS OF CLASS III CHAMBER BURNERS.

These forms are shown in figure 74. At the top is represented the basic form of the chamber burner. Then, under form A, is shown the simplest modifications formed by round openings in a small cylindrical casting. Here the oil and steam, each coming from their proper side of the burner, mingle in the end

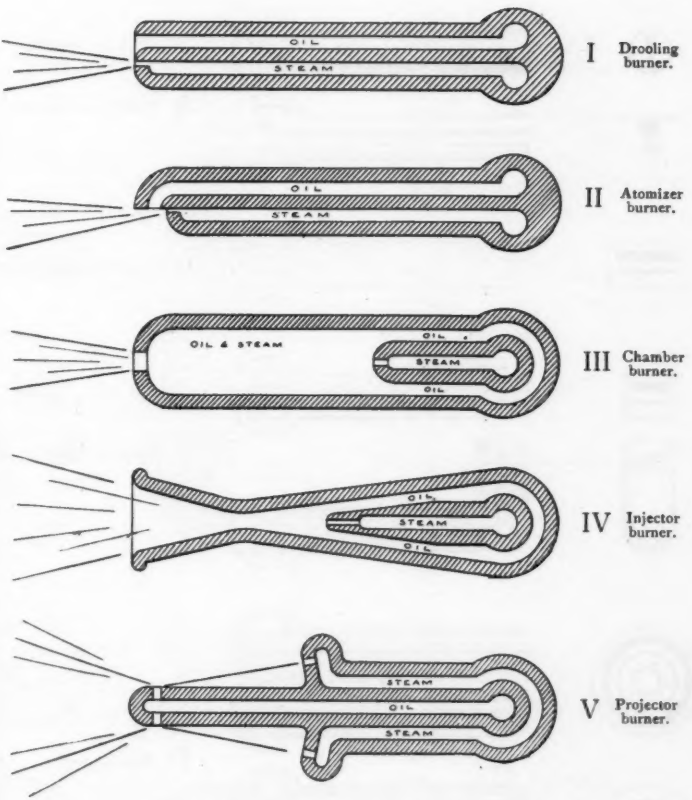


Fig. 58.—Oil Burner Classification.

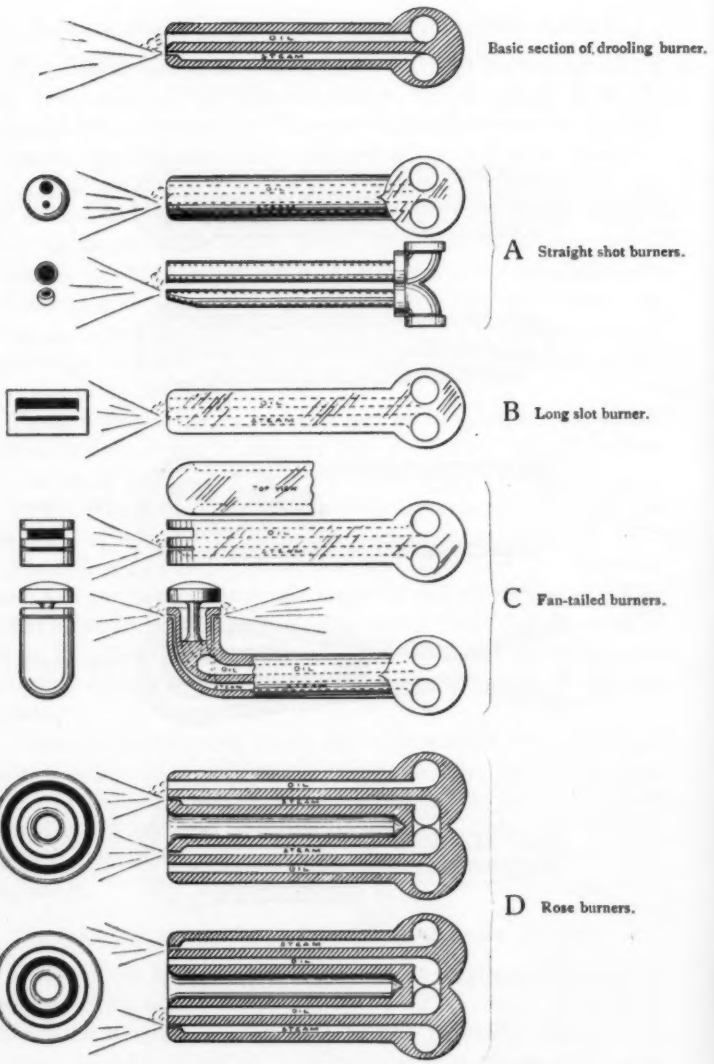


Fig. 64.—POSSIBLE MODIFICATIONS OF THE DROOLING BURNER.

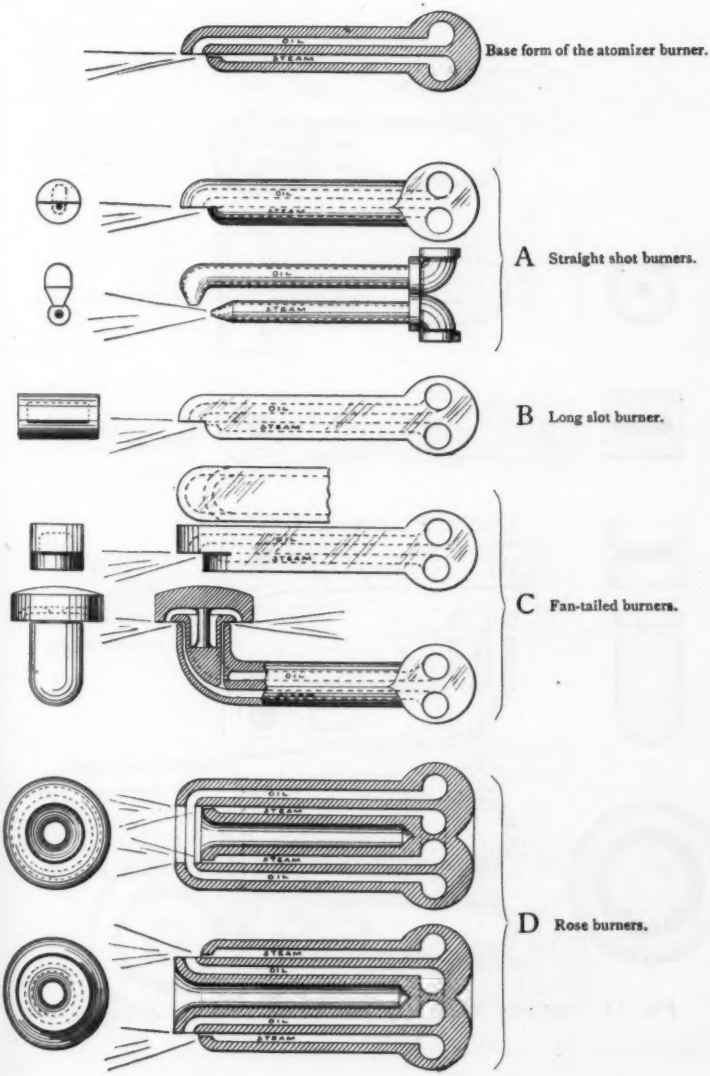


Fig. 69.—Possible Modifications of the Atomizer Burner.

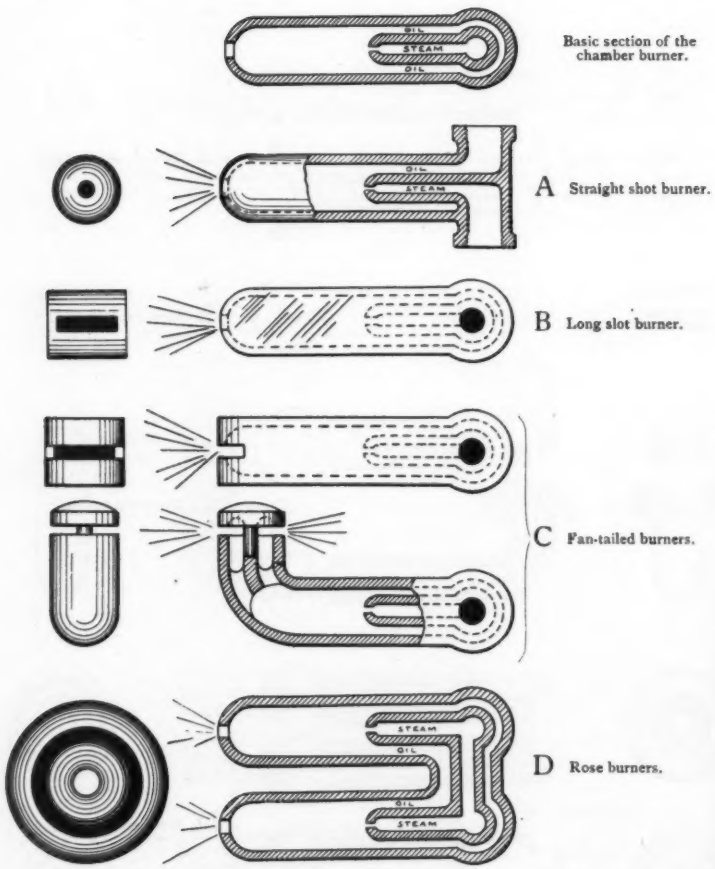


Fig. 74.—POSSIBLE MODIFICATIONS OF THE CHAMBER BURNER.

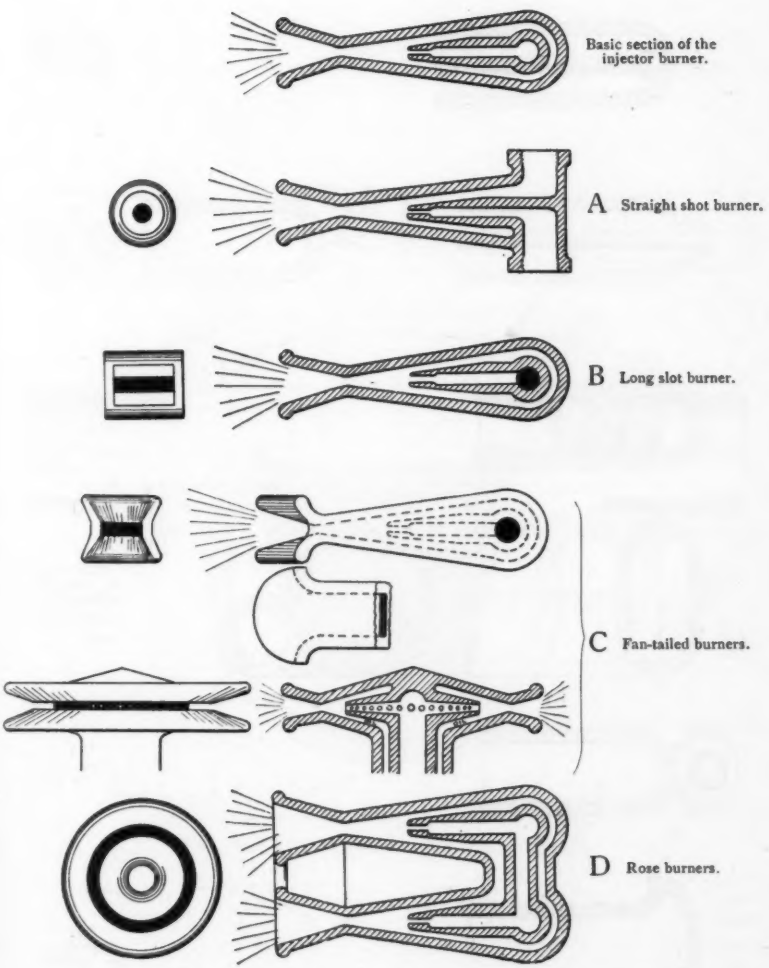


Fig. 79.—POSSIBLE MODIFICATIONS OF THE INJECTOR BURNER.

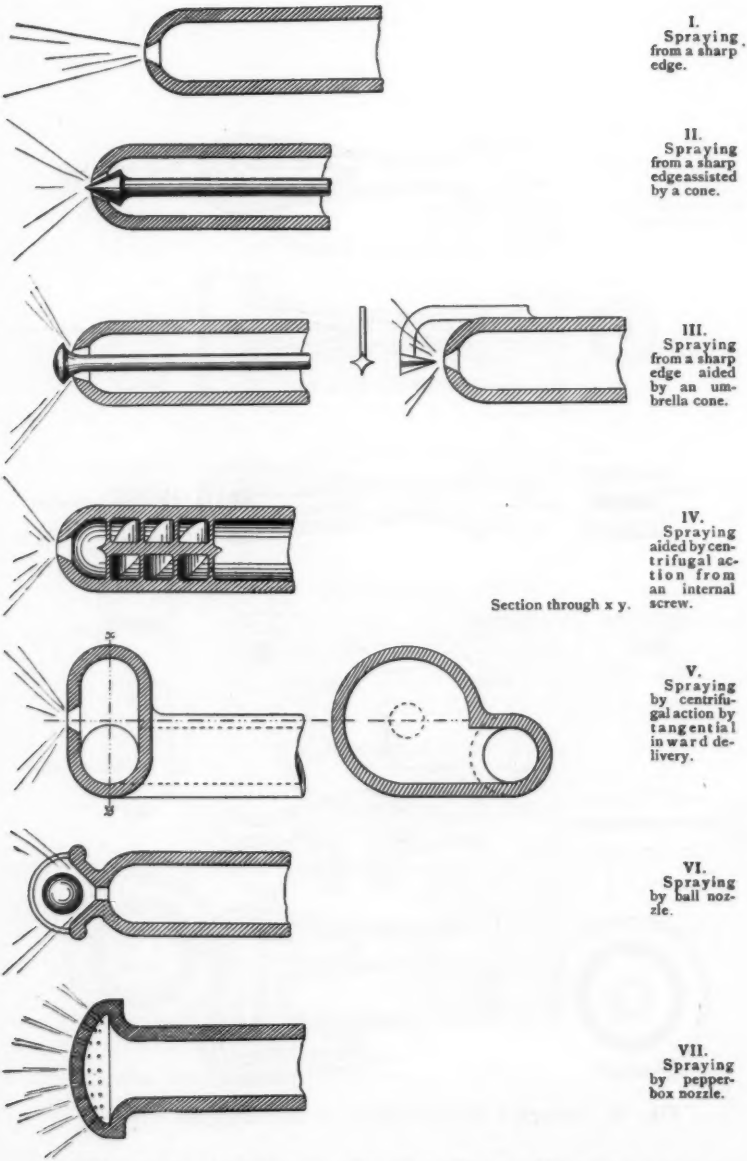


Fig. 87.—ORIFICIAL SPRAYING. FORMS OF TIPS BY MEANS OF WHICH SPRAYING MAY BE EFFECTED.

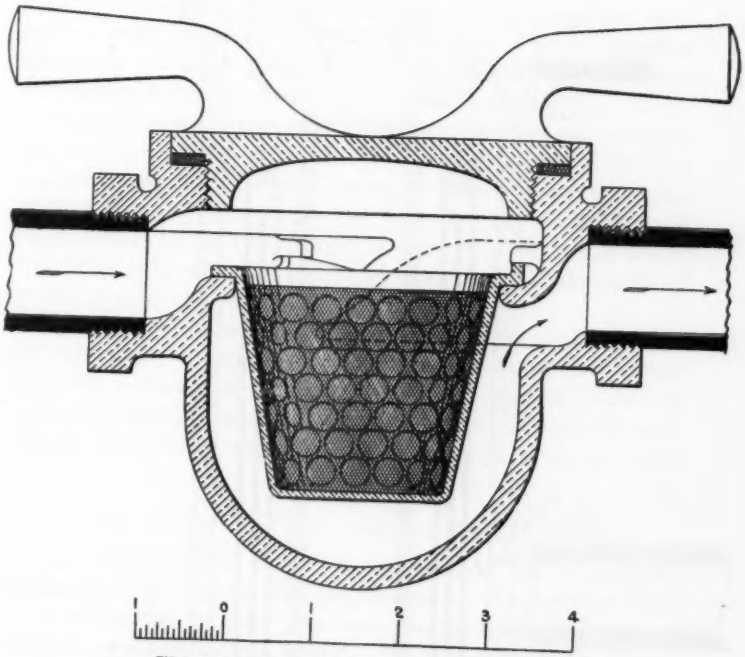


Fig. 95.—Oil Strainer for Heavy Oils.

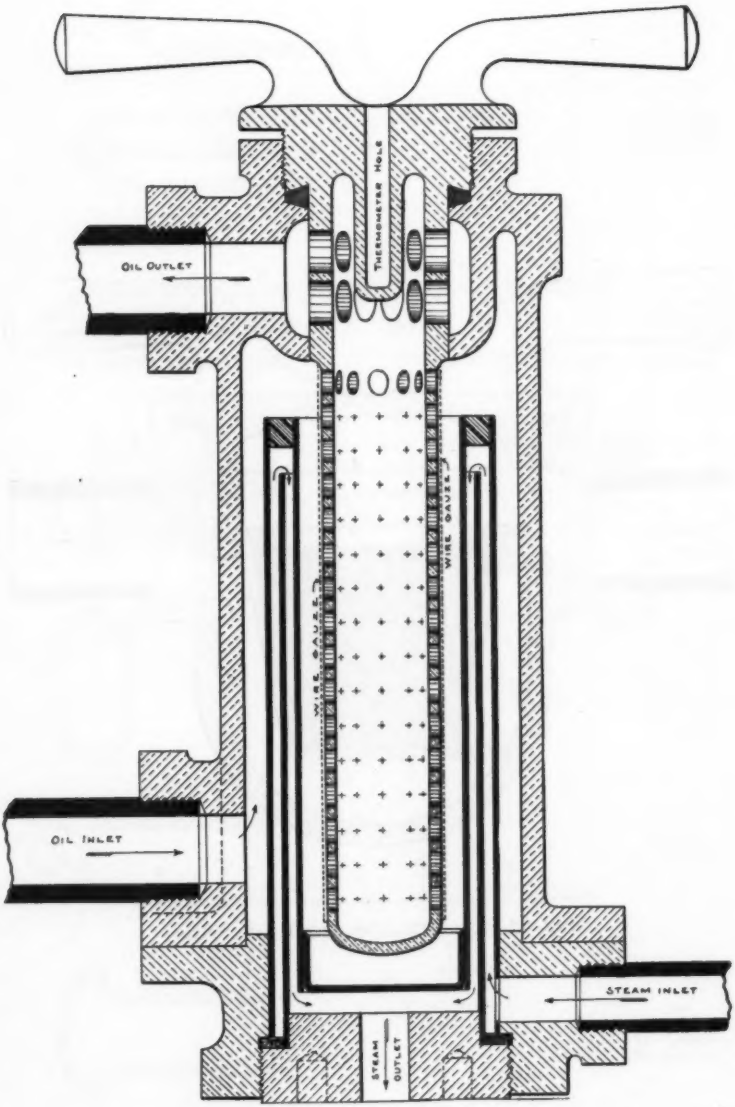


Fig. 96.—STRAINER FOR OIL, WITH OIL-WARMING DEVICE.

chamber of the burner and are ejected outward from the round orifice. It will also be observed that with this form of burner no siphonage is possible, and, in fact, if the orifices are not properly proportioned the pressure of steam may drive the oil backward to the pump.

Form B shows the same basic section of the chamber burner expanded sideways to form the long-slot burner. As thus constructed this style of burner is made use of very largely in locomotive work, on account of the advantages of large passages, which do not readily clog up, and consequently the attention demanded by the locomotive fireman is a minimum.

Form C shows two designs also derivable from the previous one and from the basic section. The upper burner of the two indicates a fan-tailed burner forming a spread of flame through a portion of an arc of a circle, and the other burner produces a flame distributed in a fan or rose shape around the whole circle. The latter style would be of service when placed in the center of grates of vertical boilers.

Form D, rose burners, shows the basic section revolved about an axis, thus forming a burner possessing an annular orifice affording a burner of very large spraying capacity, which, as with other types of burners of this rose form, are specially suitable for furnaces of large capacity or useful in smelting operations.

POSSIBLE MODIFICATIONS OF CLASS IV, INJECTOR BURNERS.

These forms are as shown in Fig. 79. At the top is represented the basic form of the injector burner. Then, under form A, is shown the simplest structural arrangement which can be devised, which consists, essentially, of a nozzle placed behind another tapering nozzle or throated opening. This is essentially a crude design of any steam injector, and, like all injectors, has the property of sucking a fluid to it under the operation of the rapidly passing steam or gas through either of the nozzles. In form A, as shown, the openings are, as usually made, of a circular cross section.

Form B represents again the same basic section of the injector,

but the orifices are extended sideways to form a slot-shaped opening. By this means its capacity as a burner or injector is greatly enhanced. Where it is desirable to use one large burner instead of the number of small ones, this form of slotted injector will give the required capacity.

In form C is shown again the injector burner designed with its mouth or slotted opening in a flaring shape, thus greatly increasing the horizontal distribution of the resulting jet of spray. By this means is thus secured a fan-shaped flame. This fan-tailed effect can be increased so as to extend through a complete circle, and this will result from the burner being conceived to be revolved about a vertical axis, as shown in the lower portion of the figures of form C. This mushroom-shaped burner would probably prove available for installation in the center of large square or round fire boxes of vertical boilers.

Form D represents again the injector burner, but the basic form is this time conceived to be revolved about an axis parallel with its center line. The resulting design will afford a burner of very large capacity, suited only for heavy smelting operations.

Types of injector burners of various styles came into very early use in the art of oil burning and still remain a standard device in many large installations. Many of these have been in use for thirty or forty years alone in the regions of the Russian oil fields, and are still mainly employed on the oil-burning railroads of southern Russia and the Caspian region.

* * * *

Before dismissing the subject of injector burners it should be said that although they have the great advantage of supplying a suction power, both for drawing in their oil or to draw in an air blast, which tends to increase their efficiency, yet it must be said that, in addition, they have the one great serious fault that they are the most noisy burners made. To install them in stationary plants or in enclosed firerooms is almost out of the question, as the noise and roar which they create is continuous, deafening and distressing, and few firemen can be found who are willing to stand regular watch in such continued racket. In locomotive work, as the burners are located, usually, outside of the cab, and

as the locomotive makes a thousand other noises in addition to the burners, a little supplementary noise is apparently absorbed in the general clatter.

Again, most of these burners being designed on the lines of the expanding nozzle, cause, in themselves, a great increase in velocity of the outgoing jet, with the result that the flame is usually one of great force and very long in extent, in proportion to the burner. The long flames might be desirable in the long furnaces of certain land boilers, but where used in the contracted fire boxes of marine and locomotive boilers the furnace design requires very serious attention, to permit of the proper upkeep of the brickwork, arches and baffling.

ORIFICIAL SPRAYING.

The classes of burners previously shown were the fundamental skeletons on which actual burners are constructed. Most of these burners can be further modified by special design of their tips or orifices, thus leading to still greater variety and often to greater improvement in their spraying qualities. These modifications of tips have been reduced to a series of classes which should be independent, as near as may be, of the other possible mechanical arrangements of the burners. As a study for the various methods of orificial spraying, the following styles of tips were considered, as shown in Fig. 87, and under any form of these tips it is found that any type of oil burner could be classed.

Form I: The design of the tip is in itself a matter of much moment, as the configuration of the tip edges has a very important physical effect on the formation of the spray, and whether the material which it is intended to spray is forced through by steam, compressed air, or even by the effect of its own pressure supplied by a pump, the edge over which the spray last passes has a determining effect on the state of subdivision of the spray. In form I is represented an ordinary nozzle with a sharpened edge at the point of exit. If a proper angle is selected for this edge, and the edge itself is well sharpened, the outgoing stream, instead of passing out in a straight line, as from a hose nozzle,

is caused to diverge, and if divergence ensues, of course there follows an expansion in the volume of the outgoing liquid which causes a condition of more or less subdivision of the particles of the fluid.

In form II is shown a design of orifice in which this effect is heightened by introducing a cone in the center of the conical orifice. The physical reason why this increased divergence is secured is due to the fact that the cone takes the place of any streams of oil which in the first case had the tendency to travel in the straight lines of the solid core of fluid. All the lines of fluid traveling down the cone surface meet in collision at the edge and tip of the cone and rapidly expand owing to the pressure which was behind them.

In form III there is again indicated the same type of sharpened cone-shaped orifice, but outside of this is placed a diverging cone upon which the outgoing spray strikes and receives a greater amount of divergence than the orifice edges would alone have produced. This diverging cone is usually placed with its stem extending within the orifice, although at the right of the diagram is shown a case where the diverging cone is supported from the outside. The amount of divergence effected by this cone can be controlled to any extent by the position or shape of the diverging surface of the cone.

In form IV there is shown an orifice similar to form I, but increased divergence of the cone of spray is obtained by circulating the fluid in a rotary manner before issuing from the sharpened orifice, the physical result of which is that as soon as the fluid leaves the orifice the effect of centrifugal action is manifested to fling the oil tangentially outward to some distance. In the diagram, as shown, this centrifugal effect is obtained by passing the fluid through spiral passages.

Form V represents the original style of orifice, but the casing is so shaped as to obtain the rotational effect of the previous tip by admitting the fluid tangentially to the interior of the chamber. The effect on the resulting cone or spray is the same as in the previous example.

Form VI: The type of nozzle is changed by inserting a ball

in the outgoing current of spray, thus mechanically breaking up the action by requiring the spray to strike the ball, this being nothing more or less than the old familiar type of the dancing ball, long made familiar in water nozzles and pneumatic nozzles as a curiosity. Its effectiveness as a spraying agent is probably no greater or as great as a well-designed and proportioned orifice of form III.

Form VII represents a class widely different from any of the preceding, which for lack of any other properly designative term might be called the "pepper-box nozzle." Its effectiveness for a certain class of burners may be made very great, but it always suffers under the great disadvantage of a multitude of small holes, which are exceedingly liable to become choked up by foreign matter or by the hydrocarbons formed at the tip of a burner while in action.

NON-SUCCESS OF APPARATUS DEPENDING ON GASIFICATION OF OIL.

The impossibility of successfully operating burners designed on the principle of superheating the oil to a point bordering on gasification has been both theoretically and practically demonstrated. The conclusions as expressed by Engineer-in-Chief Isherwood in regard to the liquid-fuel experiments conducted over thirty years ago by a Board of Naval Engineers as to the impossibility of converting liquid fuel into a gas within the burner itself hold as true now, in the light of later experiment and practice, as they were then. In regard to such burners Commodore Isherwood thus reported:

"The experiments in question embrace those made with Colonel Foote's apparatus at the Charlestown Navy Yard, and those made with other apparatus on different boilers in the New York Navy Yard, all of them, I believe, of considerable value, but never reported in full, with the exception of one made about ten years ago and which is now on the files of the Bureau of Steam Engineering. In every case the patentees abandoned the trials before they were completed, owing to the failure of their apparatus.

"The liquid oil has, in all cases, to be transformed into oil gas before it can be burned. This transformation can be made by the direct application externally of heat to the liquid, but the temperature of the oil on the vaporizing surface is higher than the temperature required to decompose it, the result being deposition of solid carbon in the form of coke, which soon fills the vaporizing vessels and renders them useless. This coke is frequently so hard that cold chisels can scarcely detach it, and if thrown into a fire, even in small fragments, it burns with excessive slowness, like graphite. Whenever the vaporizing vessel is subjected to a high temperature, like that of a boiler furnace, the decomposition of the oil and decomposition of coke go rapidly on, so that in the course of a few hours any vessel of practicable size is filled by it. All apparatus exposed to anything like furnace or flame temperature will inevitably fail from these causes in the future, as they have in the past. To make trials with such devices will merely serve to confirm this fact. The smaller the vaporization vessel and the higher the temperature to which it is exposed the more quickly will it fail.

"A very large variety of apparatus has been invented, embodying substantially this principle or mode of direct vaporization of the oil, the only difference being unimportant variations of detail to render the inventions patentable, and in all cases the vaporizing vessel has been necessarily small in order that the pressure heat could be employed in the oil vaporization, and the highest possible temperature was used in order that a sufficient quantity of the oil might be vaporized in a given time. None of the apparatus when pushed to the maximum will last more than half a dozen hours.

"It is quite possible, however, to vaporize the oil by the indirect application of heat by means of steam or water intervention, so that the temperature of the vaporizing surfaces will be below the temperature of decomposition of the oil. This would be manufacturing oil gas in a costly manner, and the gas could afterwards be burned in jets in a furnace like illuminating gas, but it would not be "burning petroleum," or any oil, in the proper sense. The vaporizing apparatus to produce the requisite quan-

tity of gas per hour for any considerable power would have to be enormously bulky, heavy and expensive—in fact, a complete gas-making plant itself; and I do not believe after the gas is obtained that a sufficient quantity of it could be consumed per hour by any practicable arrangement of jets in a furnace to produce as much heat as could be obtained from coal burned at the maximum in the same furnace.

"The only method that has been attended with any success is that of "atomizing" or spraying the oil, by means of steam under sufficient pressure for the purpose, used in an injector, placed outside the furnace so as not to receive the high temperature of combustion. The oil in fine spray, excessively comminuted, is thus squirted into the furnace, where it is decomposed at large and its constituents separately consumed. An ordinary Giffard injector is employed, and the smaller its nozzle the better it works. Even in this case, however, the injector will fill with coke after a considerable time, and requires to be unscrewed from its pipe and cleaned out, another being substituted meanwhile. In this manner oil fuel can be satisfactorily burned. All other methods have failed."

NECESSITY OF EFFICIENTLY INSTALLING ALL AUXILIARY APPLIANCES.

Strainers.—The majority of the crude oils having been obtained from wells driven into the earth, of necessity carry in the body of the oil, certain small proportions of water, more or less intimately mixed, as well as more or less sand or grit. The heavier and more viscous the oil, the greater the tendency there is to hold in suspension these deleterious substances. Large proportions of these foreign matters separate out while the oil is stored in the producers' tanks, but when the oil is hurried to a market the dealers are not always as careful as they might be to extract these harmful substances.

In general it can be assumed that no crude oil is perfectly clean. Therefore in the installation of any oil-burning plant special provision should be made for straining out all sand and foreign matter. Arrangements should always be provided for

catching the water as it slowly settles to the bottom of the tanks or bunkers.

The effect of sand in oil increases the wear on the small annular nozzles of the oil burner, or, when using burners provided with specially small orifices, these openings may become altogether clogged.

Various types of strainers for oil have been devised, some of which are simply formed by the insertion of a blind, wire-gauze gasket in the joints of the oil pipe. This device, while having the merit of simplicity, yet proves as a working method to be unsuitable, owing to the long time required to unbolt the joints to take the gauze out for cleaning. A much more satisfactory plan is to employ appliances devised on the lines of strainers used in other classes of marine work, such as Macomb strainers, etc. A strainer of this type, as designed by the Board, is shown in Fig. 95. An advantage of this type of construction is that the wire gauze is placed on the inside of a perforated metal basket. This metal basket is of such shape that it can be readily removed by giving it a slight twist and releasing it from the lugs which hold it in place, and the basket can be then removed through the top of the strainer casting, which is fitted by a cap, kept in position by two handles or ears which are formed on the cap top. As thus shown, the whole operation of taking out the strainer can be done by hand, without recourse to tools or wrenches. The strainer basket, once removed, can be replaced by a fresh and clean one.

The gauze used for oil strainers should not be too open, and should be formed of brass wires of probably a width of mesh work equal to about half of the width of oil orifice in the burner.

Another form of strainer is as represented in Fig. 96, which has been largely used in the European work undertaken with the Korting mechanical burner. As the oil orifice in those burners is only about one-sixteenth of an inch in diameter, it is therefore of utmost importance that the oil be carefully strained through very fine mesh work. In the plan as shown the wire gauze is placed around a perforated cylinder, and the oil is

forced from the outside of the cylinder through the mesh work, then into the perforated cylinder, and to its outlet. This type of strainer is also generally provided with an oil warmer, for, as we have seen, with very viscous oils it is often desirable to give them a moderate heating in order to increase the fluidity. In this filter-heating device an internal steam jacket is provided through which either light-pressure live steam or, preferably, exhaust steam from any of the auxiliary pumps can be passed.

In the placing of these strainers it is not unusual to find a strainer placed on the oil pipe on each side of the pump, thus insuring that no grit gets into the pump, and that any particles of old packing or other material from the pump cannot go to the burner through the last filter. A still more desirable plan is to have two strainers between the pump and the burners, so that when one filter is being opened the current of oil can be transferred by means of a by-pass valve through the other filter.

SEPARATION OF WATER.

There is no practicable device that will directly separate the water from the oil. This separation can only be satisfactorily effected by allowing the water to settle to the bottom of the tanks by gravity. It therefore follows that if the suction to the oil pumps is placed in the bottom of the tanks water will be often drawn when only oil is desired. A thread of water blown into the oil burner effectually extinguishes the flame in the furnace, and if oil does not soon follow the water, there may be difficulty in relighting without introducing an outside flame. In order to insure a supply of oil from the tank without an admixture of water, devices have been adopted whereby the oil-suction pipe is caused to swing up or down in the oil bunker to a level at which it is known that pure oil can always be obtained.

Fig. 97 shows a practicable design used in English tank steamers in which this movable oil-suction pipe is carried by a float. The suction tip is thus always maintained at a point within a few inches of the top of the oil wherever the oil level in the tank may be at the time. It will also be seen that the tip of the oil-suction pipe is surrounded by a steam-heating coil, the object of

which is to slightly heat the oil in proximity to the inlet, thus increasing the fluidity of the oil, so that even in cold weather the oil may be readily pumped.

At the bottom of each bunker there should always be provided a water cock or blow-off for the purpose of blowing off any water which may be found to have settled in the tank or compartment.

HEATERS FOR OIL.

Certain crude oils at the ordinary temperature of the atmosphere are of great viscosity, which viscosity increases as the temperature gets lower. At 30 degrees to 40 degrees Fahrenheit, which is not an unusual outdoor temperature, the fluidity of the oil is so slight that it is almost impossible to pump the oil or to force it to the burner. It is therefore necessary where fuel oil is to be used in regions which are subjected to severe winter temperatures that there should be means for heating the oil so that the oil may more readily flow to the pumps. The usual manner of accomplishing this is not to attempt to heat the whole tank or bunker of oil, but simply to heat the oil immediately surrounding the suction pipe to the pumps. This can be easily accomplished by placing a coil of a few turns of steam pipe about the suction pipe. This method is also shown practically accomplished in the previous figure 97, where this heating coil was attached to the floated pipe.

In all pipes intended for the transmission of crude oil it is desirable that connections should be made to them so that steam can be turned into the pipes after shutting off the oil. These pipes can be thus cleaned by the heat and the force of the blowing steam, and any deposited asphalts, paraffins or condensed hydrocarbons can be cleared out before the pipes become choked so as to impair their efficiency.

The heating of the oil should be always recommended as an aid to secure better operation of pumps and burners, but, as shown elsewhere in this report, this heating should never be carried to such a degree of temperature as will cause decomposition of the hydrocarbons of the oil. The degree of temperature at which

such decomposition is likely to occur has been ascertained for the oils of each region.

FEED TANKS FOR BURNERS.

Many installations for oil burners use a secondary feed tank between the main bunkers and the pump. This tank is designed with the intention of holding an easily measured quantity of oil, and the number of times it is filled and emptied indicates a convenient method of measuring the total number of gallons or barrels used in a stated time. This feed tank is often provided with heating coils, and the temperature is always kept at a figure just short of the depositing point of the hydrocarbons.

OIL-PRESSURE REGULATORS.

With most burners it is desirable that a uniform pressure should be maintained on the oil circuit to the burner. If it were possible to keep the pumps automatically and perfectly regulated, a uniform pressure could be secured. There are many devices on the market which set out to secure this uniformity of action. Oil-pressure regulators similar to those used as regulators on steam mains have been tried, but in general have been found to be unsatisfactory, owing to the fact that the moving parts become clogged with sand or hydrocarbon; consequently the Board has found that no so-called oil-pressure regulator used as a single device is satisfactory. A reliable plan is to provide the oil chamber of the pump with what would correspond to an air chamber on the water pump, or to provide a separate tank or chamber in which a constant air pressure is maintained on top of the oil by additional means. There are a number of designs of apparatus on the market which contain this feature of an oil air chamber, and corresponding regulating apparatus, which have given satisfaction. Many of these installations contain automatic arrangements whereby the change of level of the oil in the chamber effects a control of the steam supply to the oil pump, and thus affords an automatic method of controlling the quantity of the oil supply to the burner system.

In all oil installations it is very important that the control of

the oil pump and of the steam to the burner or of the compressed air, where air is used, should be so arranged that in case the delivery of any one of these fluids is reduced, or interrupted, a corresponding reduction or shutting off should be effected in the supply of the other elements. It is especially important that oil should in no case continue to be forced or pumped to the burners when the steam or air required for spraying is shut off, as in such an event the unsprayed oil is liable to flood in upon the hot brickwork and a furnace explosion is sooner or later likely to occur. The underwriters' regulations in many cases specifically require that in the event of the stoppage of the oil flow to the burner all the other functions shall be caused automatically to cease. These are precautions dictated by considerations of ordinary safety, and various applications of valves and devices are in the market whereby these results can be attained.

OIL-CARGO PUMPS.

For vessels carrying oil in bulk or for carrying oil in large quantities in their own bunkers it will be found desirable to install a special pump for the rapid pumping of oil either into or out of the cargo holds or ship's bunkers. Most oils, being sluggish in their motions cannot be readily handled by the pumps ordinarily used for the burners, and pumps of larger capacity are therefore required.

These cargo pumps will also be called into service while the vessel is at sea, for pumping the oil from one bunker or hold to another, in order to change the trim of the ship or to keep certain tanks at a desired level.

TANK VENTILATION.

In the storage of fuel oil on shipboard, it is of the highest importance not only that the most careful attention should be devoted to the method and quality of riveting, to secure oil tightness of bunkers and double bottoms, but that great care should be exercised in the design of the oil-tank ventilation devices. It is well known that all crude oil generates more or less vapor of an explosive nature, and this vapor being heavier than the air,

rests upon the top of the oil in tanks or bunkers. This vapor can be removed by natural or artificial means, but as the formation of the vapor from a tank of oil proceeds rather slowly, it is usually found that a system of natural ventilation can be devised so that sufficient of the vapor can be easily removed.

All ventilating heads or cowls should proceed as direct as possible to weather decks, but should be located not too near the smoke stack. In all circumstances the oil ventilating cowls should be fitted with fine wire gauze soldered into the cowl opening. This wire gauze permits easy exit of vapor, while preventing any back flash into the vapor pipe from a stray spark from the main funnel or a light from a careless smoker on deck.

These oil ventilation cowls from their very exposed position are often caught by the rush of heavy shipped seas, and salt water is likely to pour down into them. Hence it is desirable to goose-neck these cowl pipes, as is often done on board torpedo-boat ventilator pipes, or to design a cowl pipe with a light ball float which will close under the presence of water in the manner of a check valve.

AIR COMPRESSORS.

In marine work it is generally recognized that compressed air should be used as a spraying medium rather than steam, in order to prevent the loss of fresh water which is entailed by the use of steam as a spraying medium. In the types of burners generally used the amount of compressed air required is considerable, and the sizes of air compressors installed are such as to constitute quite an addition to the mechanical apparatus placed in the engine room.

By reference to the columns giving the quantity of cubic feet of air used for boilers in the tests, as conducted by the Experimental Board, it will be observed that the cubic feet of free air required to effect vaporization for a given horsepower or fuel consumption is such that the size of the air compressor demanded is considerable.

The result of these considerations is that for marine purposes when vessels are intended for short voyages it will probably be

found more satisfactory to buy water at the ports of call rather than to use the large and cumbersome air compressors required.

In very small marine installations, such as on tugs, air compressors of the Westinghouse air-brake type have often been used, but their proportional power consumption of steam is so excessive that their use is in no case to be recommended except where first cost or only occasional service is a ruling element.

Certain classes of burners have been operated with air at much lower pressures by use of blowers rather than air compressors. For marine purposes the results are somewhat more satisfactory, probably, than with the compressors, but still the blowers occupy considerable room in the engine or boiler rooms, and, as seen from the results of tests made by the Board, there is somewhat of a question whether as satisfactory a combustion can be obtained with burners under low-pressure as with burners operating under high-pressure air.

When using air either at high or low pressure as a spraying medium it is exceedingly desirable that the air be superheated before passing to the spraying tip, as thereby a considerable gain in efficiency can be anticipated.

FURNACE CONSTRUCTION.

Where there is no desire to force the combustion of liquid fuel, the simple cylindrical furnace of the Scotch boiler has been found fairly suitable, particularly if an extension to the front of the furnace is made, so that complete combustion can be effected before the gases pass through the tubes.

With the water-tube boiler the problem becomes a more complicated one, at least so far as economy is concerned. Where the gases pass through the tubes, as in the case of the Scotch boiler, the resulting friction is sufficiently great to cause the gases to be abstracted of sufficient heat to produce a comparatively low temperature at the base of the stack. Where the gases pass around the tubes, as in the case of a water-tube boiler, there is but little impeding of the flow, and as a result stack temperatures are comparatively high. When burning oil in bent-tube types of boilers

combustion is often only completed near the top rather than near the base of the stack or funnel.

The question of baffling of the gases in a water-tube boiler is one of supreme importance, for not only does it concern the economic efficiency but the endurance of the boiler itself. The straight-tube water-tube boiler ought, however, to possess special advantage for the burning of oil by reason of the fact that it is possible to secure a combustion chamber of considerable volume, so that complete combustion of the fuel can be effected.

Valuable information in relation to the naval boiler problem could have been obtained if the experiments had been continued sufficiently long to have experimented with different arrangements of baffling. There is but little doubt that it would have been found that the calorimeter opening should be decreased in a water-tube boiler where either coal or crude petroleum is used as a fuel. It will be observed that in some of the experiments where forced draft was used the reduced calorimeter opening proved very effective. Throughout the experiments it was apparent that in many respects the baffling of gases in modern water-tube boilers has been done, and that unsystematically the relative efficiency and endurance of the various types can only be determined by the installation of a more efficient system of baffling.

It must be manifest that the question of water circulation is greatly dependent upon the problem of baffling, for unless there is a comparatively uniform heating of the tubes spasmodic circulation in water-tube boilers of every design is likely to occur.

The remarkable freedom from bending of the lower row of tubes of the experimental boiler was undoubtedly due to the presence of the horizontal baffle plates placed between the tubes for two-thirds of their length. As this baffling reached an incandescent state there was radiation from it to the lower row of tubes when the furnace doors were opened, and thus the tubes themselves were uniformly receiving heat either from the gases or from the intervening baffling. The fact that the lower row of tubes in the Hohenstein boiler was practically immune from a

tendency to bend could only be ascribed to the nature of the baffling and the excellent character of construction.

Numerous experts had suggested to the Board the necessity of giving special consideration to the question of arch construction so that there could be an impeding of the flow of the gases, in order that combustion could be completely effected within the furnace or amidst the tubes.

The more experience the Board had with arch construction the more convinced the members became that by reason of such construction being subjected to very severe heat and occasional chilling but little endurance could be expected. Before settling, therefore, upon any approved form of baffling arch the effort should be made to dispense entirely with any brickwork except a lining for a portion of the furnace length and a simple vertical bridge wall whose height could be increased or diminished at comparative trifling time, trouble and expense.

FURNACE FORMS FOR SCOTCH MARINE BOILERS.

Scotch marine boilers, on account of their contracted volume of furnace, produce difficulties in the introduction of oil, and by reason of the small cubical space permissible for combustion purposes it is requisite that careful study should be given to the disposition of the brickwork in, or surrounding a furnace. It is, of course, quite possible to spray the oil at once into the metallic fire box or furnace of the Scotch boiler, the flame impinging on the cold surfaces of the steel plates; but although this is often done, yet it can not in any case be recommended as good practice. For successful combustion of oil it is requisite that the issuing oil spray should not too early in its progress of combustion strike the chilled or comparatively cold surfaces of the metal work. Carefully designed oil-burning furnaces require that the furnaces should be either partially or wholly bricked around.

As has been elsewhere shown in this report, the fact of heated brickwork is in itself a very great advantage in aiding combustion, and of still greater use in insuring perfect continuity of the heat supply, especially when burners tend to act in gusts, as

they often do under improper action of the pumps, or where there is dirt or water in the oil supply.

The brickwork surrounding the interior of the Scotch furnace, ought not to constitute a serious loss in thermal effect, because the brick itself early becomes incandescent and transmits a large portion of its heat directly to the metal in a steady and continuous flow.

OIL-BURNING FURNACE FORMS FOR WATER-TUBE BOILERS.

Water-tube boilers have usually somewhat greater volume in their fire boxes than the furnaces of the Scotch boilers, consequently the opportunities are greater to arrange the brickwork to suit the peculiar conditions required by oil fuel. With most of these boilers it is quite customary to put the burners into the fire doors or the spaces which would have been occupied by fire doors. As a matter of fact, it would often be better to put the burner at the back of the boiler and fire toward the front of the furnace, as by this means the larger end of the furnace would receive the gases of combustion at the point where the greatest expansion was taking place.

Owing to the fact that all the gauges, fittings and connections are on the front of the boiler, it therefore becomes an advantage to have the burner also located on the front rather than on the back, where it would be practically inaccessible. In all the tests of the Board and in the proposed furnace modifications submitted the burners have been installed in the front of the furnace.

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STRUCTURAL, TRANSPORTATION AND SUPPLY FEATURES OF THE OIL-FUEL PROBLEM GREAT BARS TO THE USE OF SUCH FUEL ON BOARD FIGHTING SHIPS.

The mechanical or engineering feature of the oil-fuel problem has been practically solved. The financial feature should not be regarded as of serious importance in the solution of any naval fuel problem, since it would be just as logical to fill the magazines of a warship with an inferior quality of powder as to stow the bunkers with a poor steaming fuel. The question of cost as

to fuel supply for naval purposes should not, therefore, receive undue consideration.

At the present time it is the structural, transportation and supply features which present the only serious difficulty to the adoption of the use of liquid fuel by the navies of the world.

The more carefully, however, the structural problem as regards a fuel installation on a battleship is considered, the more difficult and complicated appears its solution. The storage of oil fuel on board the armored cruiser or battleship, or what might be termed the structural feature of the problem, is thus undoubtedly the great deterrent to the use of what may popularly be regarded as an incomparable fuel for warship purposes.

In the warship, the oil fuel will probably have to be carried below the protective deck; in fact, as far below the water line as possible. In the merchant service the tanks often rise to the height of the main deck. In the warship, however, considerable space must be found in the lower portions of the vessel for the storage of ammunition and ship's equipment, thus rendering it exceedingly difficult to secure beneath the protective deck sufficient space for the storage of the oil supply.

Crude oil is a great searcher, and unusual care will have to be exercised in the construction of tanks or receptacles on board warships for the stowing of such fuel. Some of the resulting gases from the volatilization of liquid fuel are not only poisonous but explosive, and, being much heavier than air, their removal from the storage tanks will be a very difficult matter.

Not only will it be necessary to increase the number of fuel compartments if oil is substituted for coal, but greater care will have to be exercised in making the bulkheads tight. In order to increase the safety of such vessels it would be essential to have the various oil compartments absolutely distinct from each other.

In the loading and unloading of oil-carrying steamers, fires are always hauled from the galleys and boilers of the vessels. On board the warship, where a large crew has to be housed, the putting out of the galley fires would subject the crew to much inconvenience. The modern warship is now crowded with so many

auxiliaries that steam must be maintained in some of the boilers of naval vessels at all times, and therefore the dangers attendant upon the stowage of oil in warships will be much greater than that in merchant vessels.

It is the belief of the Board that if oil fuel is ever used on board warships it will be essential to make the containing walls of the oil tanks much heavier than in the case of the ordinary watertight bulkhead. The formation of heavy gases that will accumulate as the amount of liquid fuel decreases will constitute a great danger. The more the tanks are depleted the greater will be the danger from a possible explosion. The general structural arrangement of the battleship even now is of such character that the satisfactory ventilation of every compartment has not been secured, and particularly will such be the case where the fuel supply is of oil rather than of coal.

In all probability the great bulk of the oil in the warship would have to be kept in the double bottoms. As the petroleum vapors are quite heavy, it may be a difficult matter to free these compartments of explosive gases, especially when the compartments are partly empty. By reason of the great number of electrical appliances in use on board the warship hundreds of sparks are likely to be caused, any one of which might cause an explosion and set the oil fuel on fire.

In submarine boats no effective way of rapidly removing the noxious and explosive hydrocarbon gases from the gasoline engines has yet been devised, although the hulls of such boats are simple spindles with a large opening or conning tower in the center. Experience with gasoline vapors in this class of naval construction will give some idea of overcoming the greater problem of removing gases from the numerous small compartments of a battleship. The difficulty of freeing the compartments of the heavy and explosive gases is almost a problem in itself, and will require extended investigation and experiment before any naval power seriously considers the proposition of installing an oil-fuel system exclusively on board a warship.

With oil as a fuel it will be essential to provide a very complex installation of piping. It may be necessary to make arrange-

ments whereby live steam can be admitted to each compartment for the purpose of putting out fires and also for the removal of the heavy gases. The condensed water resulting from this steam will have to be removed to prevent corrosion of bulkheads. Experience may also show the necessity of having a system of piping whereby the oil compartments could be flooded. Exceeding care will have to be used in making all joints, for if any leakage should reach the bilge, and if the oil should then rise through the flooding of the bilges to the level of the fireroom plates, the safety of the vessel might be endangered.

In the case of passenger and freight steamers, the vessels are of sufficient length to permit the main supply of oil to be carried in an expansion trunk or bunker extending the full width of the ship. It is also possible to have a cofferdam both forward and aft of this bunker, and thus leakage is quickly detected before such leakage has a chance to reach the double bottoms under the firerooms.

THE SMOKE NUISANCE.

One of the principal reasons heretofore advanced for the general use of oil rather than coal as a fuel for naval purposes was the advantage that would accrue from the abolition of smoke. It seemed to be regarded as a matter of certainty that, with the use of oil, complete combustion of the fuel could be secured before the gases reached the base of the funnel. Possibly three-fourths of those who advocated the substitution of oil for coal, as a fuel for naval purposes, had not the slightest doubt but that the prevention of smoke would thereby be as certain as the obliteration of refuse in the ash pan.

There was hardly a naval writer who, in discussing the probable advance in naval construction, did not dwell upon the early prospect of dispensing with coal, and of the advantage that would ensue in having a fleet maneuver or establish a blockade, using such an incomparable smokeless fuel as crude oil. There were some naval strategists who regarded this advantage as one of the most important advances that would ensue in matters pertaining to naval engineering during the coming decade.

Where the oil used has passed through several stages of re-

fining, and wherever a limited amount of oil is burnt in an exceedingly regular and uniform manner, then where an adequate and regular supply of air requisite for combustion is furnished, no smoke need appear. The ordinary household lamp may be regarded as an appliance for burning oil wherein all these necessary chemical and natural conditions are fulfilled.

On shore it is possible to approximate to many of the necessary conditions essential for securing complete combustion in the burning of oil, for in the installation of a land boiler there are but few limitations as to weight, floor space or height. In arranging a battery of land boilers there can be effected such an installation that the management of the firing can be absolutely controlled by some intelligent and competent water tender. The height of the stack need only be limited by the judgment of the engineer who designed the plant. And yet on shore the burning of oil, as fuel, in large quantities has been carried on only with extreme difficulty as regards smoke, particularly when there has been an attempt made to force the fires.

An examination of the remarks made in connection with the different oil-fuel tests of the Board, will show that whenever an attempt was made, under severe forced-draft conditions, to secure an exceeding large evaporative capacity, the smoke nuisance was encountered. By an arrangement of mirrors, the condition of affairs as regards smoke at the top of the stack, was always under observation by the water tender; and the ability to make such observation was of inestimable benefit in calling attention to the condition and thus leading to a readjustment of burners to secure a reduction of the smoke.

Careful and long-continued observations upon the question of preventing smoke, convinced the Board that with the use of water-tube boilers, as compared with the fire-tube boilers, the difficulty of effecting complete combustion before the gases reached the base of the stack had enormously increased. The result of investigating the smoke problem only confirms the following opinion, formed by the study of the question of the efficiency of water-tube boilers, and that is that the weakness of the modern water-tube boiler lies in its inefficient system of baffling.

This baffling is of such a nature that it is almost impossible, under heavy forced-draft conditions, for complete combustion to be effected within the proper places, or for low stack temperature to be secured.

The burning of 40 pounds of coal per square foot of grate, or 25 pounds of oil per square foot of sectional furnace area, should be demanded in boilers of the modern battleship. The great cost of these warships, approximating over $7,500,000, combined with the fact that these vessels are primarily built for the day of battle, makes it absolutely necessary that the boilers should be capable of severe forcing. It is also essential that their endurance under varied conditions should continue for at least six years after commissioning. The abolition of the smoke nuisance, when either coal or oil is used as a fuel, or when the consumption is forced beyond 40 pounds of coal per square foot of grate, or an equivalent consumption of oil, will probably never be accomplished for extended work until more space is given for the installation of boilers and fewer limitations are placed upon the weight and height of these appliances. The firerooms of the present battleship are so crowded with auxiliaries, and these auxiliaries are expected to serve so many purposes, that practically every condition for ideal firing, as compared with the land installation of boilers, has been obliterated.

The existence of the smoke nuisance alone should cause naval experts to investigate the question as to whether the time has now arrived when a saving of weight effected by the removal of luxuries installed above the protective deck will permit such space and weight thus gained to be assigned to an improvement of the boiler installation, and when it would be possible to secure more complete combustion of the fuel under forced-draft conditions.

In the attempt to prevent the smoke nuisance on board the warship, particularly where oil is used as a fuel, it should be kept in mind that the installing of the boilers in different compartments produces different steaming conditions in the several stokeholds, owing to the greater ease with which air finds its way into some compartments as compared with others. Every

marine engineer of experience knows that by reason of their location certain boilers steam more freely than others.

That there is a difference in the natural air supply of the several fireroom compartments is evidenced by the fact that the fireroom force always find, when the ship is under steaming conditions, that certain compartments are more habitable than others. By reason of the structural arrangement of the ship, it will probably be found impossible for the water tenders in the various compartments to observe whether or not smoke is issuing from the funnel of the several boilers under their charge. Where several boilers discharge the products of combustion into one funnel, the problem is still further complicated. Inspection of the flame through peepholes in the furnace front is less satisfactory for detecting smoke than a glance at the funnel top. In view of the extended experience acquired in the conduct of these oil tests, it can be safely affirmed that the smoke nuisance is likely to prove more obnoxious with the use of oil than with the use of coal as a fuel in warships fitted with protective decks, with an installation of water-tube boilers under forced-draft conditions.

It is hopeless to expect an improvement in this respect until naval experts are ready to sacrifice either some of the luxuries or a small amount of the armor, so that the gain in weight secured thereby will permit the lengthening of the ship to a degree that would not only permit more floor space, but allow additional weight for the installation of the battery of boilers. A simple change in the form of the arch of the protective deck might, in some cases, greatly improve matters, since this change would permit a much desired increase in height for installation of boilers and also render possible the introduction of some form of economizer that might be fitted in the uptake.

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NECESSITY OF RAPIDLY AND CLOSELY REGULATING THE ADMISSION OF AIR REQUISITE FOR COMBUSTION.

Where oil is used as a fuel, there should be determined, by practical experiment for various conditions, the size of openings in ash pits requisite for admitting air essential for completing

combustion. In the use of liquid fuel there will always be a tendency to admit too much air, and this should be checked by the installation of a series of dampers whose opening could be closely regulated.

Where coal is used on the grates, such fuel remains for an appreciable interval of time on the bars, and thus checks the passage of air from the ash pit. The bed of incandescent fuel thus limits the amount of air that will reach the combustion chamber.

Where oil is used as a fuel there is no corresponding interference with the draft from the ash pit. On the contrary, the heating of the air increases the velocity of the current. The reduction in the time available for the diffusion of the particles of oil with the air undoubtedly more than offsets the advantage due to the rapidity with which the subdivision of the oil particles is effected.

One of the principal problems in successful oil burning will thus be to impede the flow of the gases so that complete diffusion of the particles of oil will take place in the combustion chamber and amid the tubes. Such devices as bridge walls, arches, deflectors, baffles and other forms of furnace construction undoubtedly check in part the flow of the gases. The difficulty of impeding the flow of the gases will, therefore, prevent the economical installation of oil burners in special forms of bent water-tube boilers. It is probable that oil-fuel installations in marine water-tube boilers will be limited to those types which admit of extensive baffling.

Precautions should also be taken that large volumes of air are not suddenly admitted to the furnace; otherwise these cold currents will cause soot to be deposited on the surfaces of the boiler.

Where too much cold air is admitted above the burners, through the furnace front, there is a tendency to produce noise; in some cases there will be resulting explosions, sufficient to shake the boiler casings. The problem, therefore, as to the quantity of air which should be admitted for completing combustion, as well as the manner of admission of this air, will have a very important effect in many ways upon the satisfactory use of oil as a fuel, either for manufacturing or marine purposes.

INFLUENCE OF HYGROMETRIC CONDITION OF THE ATMOSPHERE AS REGARDS EFFICIENCY AND CAPACITY.

The oil-fuel experiments had been conducted but a short period before it was observable that the hygrometric state of the atmosphere had an important influence upon both evaporative efficiency and evaporative capacity.

That the humidity of the atmosphere is a determining factor as regards evaporative efficiency was specially demonstrated during test No. 15, of October 4, 1902, in the log of which appears the following remarks:

"This test was intended to be a reproduction of that of September 22, and was to develop a possible correction to be applied to the records of September 19, 20 and 22, on account of the dirty condition of the boiler during those tests (it having since been blown down and the tubes cleaned of soot).

"With the same air openings into the furnace as on September 22, and with almost exactly the same percentage of steam used for spraying the oil, it was impossible to burn more than 84 per cent. of the oil burned then. This can be accounted for only by the difference in hygrometric condition on the two days, the air on this run being saturated. This suggests the advisability of adding the hygrometric condition of the atmosphere to the data recorded for each run."

In the investigation of this matter both efficiency and capacity curves were plotted and compared with humidity curves for the periods covered by several tests. In each case the influence of humidity was specially noted. It is therefore reasonable to infer that when operating a boiler at a given capacity the efficiency varies inversely with the humidity.

The decrease of efficiency due to humidity can be ascribed to two causes—

First. To the displacement of a certain amount of oxygen in a given volume of air by the moisture of the atmosphere, thus requiring an excess in volume of air for completing combustion, with consequent loss of heat in the stack.

Second. To the decreased rapidity of diffusion of the com-

bustible gases with the oxygen due to the presence of the inert moisture.

The abrupt termination of the oil tests prevented the special investigation of the influence of humidity of the atmosphere both as regards the evaporative efficiency and evaporative capacity of the experimental boiler. In making comparisons between different boilers it is thus essential that the hygrometric conditions of the atmosphere during the several tests be taken into consideration.

WHERE OIL IS USED AS FUEL THE HIGHEST CHARACTER OF INSTALLATION MUST BE EFFECTED.

The Board was strikingly impressed with the fact that it will be found essential where oil is used as a fuel to effect the highest character of installation. All contemplating the use of such a fuel should regard the building of storage tanks as a boiler-maker's job and not as a work that should be intrusted to either a cooper or a tank builder. The first cost, as regards tank construction, may seem excessive as compared with the expense of having it done by manufacturers of ordinary steel tanks. It is certain, however, that increased economy and safety will result from such an installation.

The introduction of all burners and their necessary piping should likewise be intrusted only to expert steam fitters possessing considerable experience and knowledge of the action of crude petroleum vapors. The remarkable searching and destructive power of petroleum gases will be evidenced to the users of oil fuel if any cheap installation of appliances is attempted.

As it will be imperative to maintain an oil-fuel plant in the highest state of efficiency, the actual cost of upkeep of plant using oil as compared with coal will not be as economical as has been maintained. For a time an oil-fuel plant may be operated by cheap labor, but the continued employment of such men will invite disaster.

In regard to fuel-oil storage on ocean-going steamers, an observance of the following general rules will prove exceedingly

beneficial to ship owners, as well as to those called upon to operate the plant.

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For small independent tanks, not forming part of the double bottom, and which tanks are not more than four feet in height, the shell plates should be of steel of good quality and heavy enough to prevent the seams being opened by the motion of the ship or surging of the oil in any weather. It is recommended that for ocean steamers the shell plates of these tanks be five-sixteenths of an inch in thickness and for inland steamers one-fourth of an inch in thickness.

Where tanks of greater heights are contemplated, Lloyd's or other rules as applicable to watertight bulkheading should be used.

The seams of large cylindrical tanks should be double chain riveted, sheets laid close and well calked.

It is also recommended that the rivet holes be drilled instead of punched. They will then be fair, and rivets can be driven to properly fill the holes to prevent leakage.

In long tanks, suitable baffling or swash plates should be put in and securely fastened, to prevent the oil from surging. Under each small tank, when the tank is separate from the ship's structure, there is required to be a drip pan. This should be of lead weighing not less than 8 pounds to the square foot.

In deep tanks, when forming part of the structural portion of the vessel, special attention should be given to the proper and ample proportioning of the bulkhead stiffeners.

There should be no openings cut into the bottom, sides or ends of the tanks; all inlets and outlets must be through the top.

Reenforcing flanges should be of wrought steel and properly riveted to the top of the tank for filling, suction and vent pipes. All filling pipes should run to the bottom of the tanks, so that when the tanks are filled the gas will be expelled through the vent pipes.

The man-plate opening should be of ample size (11 by 16 inches may do) to facilitate getting into the tank for any purpose. The vent must have an area equal to the diameter of the filling

pipe, and should be carried up above the superstructure of the vessel, and have a non-return bend on the end, covered with a fine copper-wire gauze screen.

No fuel oil is allowed to be carried in the water bottoms under the engine or boiler rooms on steamers.

"Davie" safety lamps should be provided for engineers and for all directly employed in the firerooms, so that if the electric-light plant is shut down they can be used in place of an open-flame lamp. The regulations of the United States Steamboat-Inspection Service require that for oil burning on freight vessels there shall be valves fitted in the connection between the supply tank and the boiler. With such a valve installed the flow of oil at all times can either be regulated or cut off in case it is desired to extinguish or check the fire. Where more than one tank is used for stowage of oil, and such tanks are connected for discharge of oil from one tank to another, arrangements must be made whereby such valves can be manipulated from the main deck of the steamer.

While the number of oil-fuel installations for marine work has greatly increased during the past two years, increased consideration is being given the question of safety. It is in the direction of making such plants more safe rather than more economical that extended improvement should now be made.

THERMAL EFFICIENCY NOT INCREASED BY THE USE OF STEAM.

There is a widespread misconception regarding the part that the steam which is used for atomizing purposes plays in effecting combustion. It is supposed by many that, after atomizing the oil, the steam is decomposed and that the hydrogen and carbon are again united, thus producing heat and adding to the heat value of the fuel. While it may be true that the presence of steam may change the character and sequence of the chemical reaction and result in the production of a higher temperature at some part of the flame, such an advantage will be offset by lower temperatures elsewhere between the grate and the base of the stack. All steam that enters the furnace will, if combustion is complete, pass up the stack as steam, also carrying with it a certain quantity of

waste heat. The amount of this waste heat will depend upon the amount of steam and its temperature at entrance of the furnace. The quantity of available heat, measured in thermal units, is undoubtedly diminished by the introduction of steam. In an efficient boiler it is quantity of heat rather than intensity that is wanted. For many manufacturing purposes intensity of heat may be of primary importance, but in a marine steam generator a local intense heat is objectionable on other grounds than those of economy, viz: its liability to cause leaky tubes and seams from the unequal expansion of heating surfaces.

NAVAL RESEARCH SHOULD BE CONDUCTED ENTIRELY BY PERSONS WITHIN THE NAVY.

The Board desires to state that such experiments can not be conducted to the best interest of the service without the aid of a Navy crew of firemen and observers. It is essential that the Board should be able to call upon such crew for either day or night work. While most of the official tests were only of eight hours' duration, it required several hours to warm up the boiler and get things in good running shape. Then it requires one or two hours after the completion of the test to secure the plant and guard against fire.

A civilian crew will only work eight hours, and then at stated intervals. They demand extra compensation for overtime, and it is no easy matter to get them to stand up to forced-draft conditions, particularly when the higher air pressures are used. A crew of firemen that is changed from day to day, and who are apprehensive of their personal safety when forced-draft trials are made, can not be interested in the work.

The experimental crew must be under military control and discipline, and this can only be secured by having some vessel of the Navy, regularly in commission, assigned to duty in connection with an experimental board.

THE WORLD'S RELATIVE PRODUCTION OF COAL AND CRUDE PETROLEUM.

A careful study of the latest reports of the United States Geological Survey will show the relatively small production throughout the world of crude petroleum as compared with coal. It is

exceedingly important to note likewise that, judged from a naval standpoint, the distribution of the coal beds is much more extensive, and therefore much more advantageous by location, than that of the oil fields. This distribution of the world's fuel supply should be given special consideration in the study of the military phase of the oil-fuel problem.

When it is considered that crude petroleum is extensively used in the arts and sciences, as well as for lubricating and illuminating purposes, it is probable that less than one-half of the world's production of crude petroleum is available for fuel. Regarding 3 to 3½ barrels of oil as the equivalent of 1 ton of coal, it will be observed, from a comparison of the following tables, *that less than 3 per cent. of the world's production of fuel can possibly be secured from the use of crude petroleum.*

Independent of the question of cost, the use of oil as fuel for either manufacturing, maritime or naval purposes must therefore for a time be considered as limited, by reason of the shortness of supply.

While Russia produces about 44 per cent. of the world's output of petroleum, her oil fields are not located advantageously for use either by her navy or by foreign commerce. From a military standpoint the United States, which produces 48 per cent. of the world's output, is the only naval power which could hope to utilize to any great extent this incomparable fuel for naval and maritime purposes. This is because the Texas and California oil fields are within comparatively short distances of great maritime ports and possible scenes of naval operations.

WORLD'S PRODUCTION OF COAL.

In the following table, prepared by the United States Geological Survey, is given the coal production of the principal countries, for the years nearest the one under review, for which figures could be obtained. For the sake of convenience the quantities are expressed in the unit of measurement adopted in each country, and reduced for comparison to short tons of 2,000 pounds. In each case the year is named for which the production is given:

Country and usual unit.	Quantity.	Equivalent in short tons of 2,000 pounds.
United States (1902), long tons	269,277,178	301,590,439
Great Britain (1902), long tons	277,095,042	310,346,447
Germany (1902), metric tons	150,436,810	165,826,496
Austria-Hungary (1901), metric tons	41,202,902	45,417,959
France (1902), metric tons	30,196,994	33,286,146
Belgium (1901), metric tons	22,213,410	24,485,842
Russia (1901), metric tons	16,269,800	17,934,201
Canada (1902), short tons	7,639,225	7,639,225
Mexico (1902), metric tons	709,654	782,251
Japan (1900), metric tons	7,429,457	8,187,262
India (1902), long tons	7,433,972	8,326,049
New South Wales (1902), long tons	5,942,011	6,655,052
Spain (1901), metric tons	2,747,724	3,027,992
New Zealand (1901), long tons	1,227,638	1,374,955
Sweden (1902), metric tons	304,733	335,907
Italy (1901), metric tons	425,614	469,154
Holland (1900), metric tons	320,225	352,888
South African Republic (1901), long tons	671,532	752,116
Queensland (1901), long tons	539,472	604,209
Victoria (1901), long tons	209,329	234,448
Natal (1902), long tons	592,821	663,960
Cape Colony (1900), long tons	198,451	222,265
Tasmania (1900), long tons	43,010	48,171
Other countries*, long tons	2,000,000	2,240,000
Total	...	940,803,434
Percentage of the United States	...	32

*Includes China, Turkey, Servia, Portugal, United States of Colombia, Chile, Borneo and Labuan, Peru, Greece, etc.

WORLD'S PRODUCTION OF CRUDE PETROLEUM.

The following table gives the production, approximately, of crude petroleum in all of the known countries of the world, together with the percentages of each for 1901 and 1902, in terms of United States barrels, at 42 gallons per barrel of 231 cubic inches per gallon. A small estimated quantity has been placed under the head of "all other countries." This quantity includes a primitive production in several of the South American States, Algeria in Africa, Persia, the Philippines and China, from which no returns could be secured.

The total increase in 1902 amounted to almost 12 per cent. as compared with 1901 and to almost 25 per cent. as compared with 1900. The most conspicuous items in the list are the increase

in the production of the United States and the decrease in the production of Russia, the United States, for the first time in five years, surpassing Russia in production by 8,226,871 barrels. The United States and Russia produced, in 1902, 91.44 per cent. of the total output as compared with 93.22 per cent. in 1901 and with 94.11 per cent. in 1900. Of the remaining 8.56 per cent., Sumatra, Java, Borneo, Galicia and Roumania, which furnished only 4.65 per cent. in 1901, furnished 6.52 per cent. in 1902, leaving 2.04 per cent. of the total as the output of all the other producing countries.

WORLD'S PRODUCTION OF CRUDE PETROLEUM IN 1901 AND 1902.*

Country.	1901.		1902.	
	Quantity in barrels of 42 U. S. gallons.	Percentage of total.	Quantity in barrels of 42 U. S. gallons.	Percentage of total.
United States	69,389,194	41.84	88,766,916	47.94
Canada	572,500	.35	520,000	.28
Peru	72,261	.04	60,000	.03
Russia	85,168,556	51.38	80,540,045	43.50
Galicia	3,251,544	1.96	4,142,160	2.24
Sumatra, Java and Borneo	3,038,700	1.84	5,860,000	3.17
Roumania	1,406,160	.85	2,059,930	1.11
India	1,430,716	.86	1,617,363	.87
Japan	1,100,000	.67	1,193,000	.64
Germany	313,630	.19	353,675	.20
Italy	10,100	.02	12,000	.02
All other countries	20,000		26,000	
Total	165,773,361	100.00	185,151,089	100.00

* Report United States Geological Survey.

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THE OIL PRODUCTION OF THE UNITED STATES AVAILABLE FOR FUEL PURPOSES.

Careful consideration has been given the question as to the supply of crude petroleum in the United States available for fuel purposes. This matter has been specially investigated by Prof. Arthur L. Williston, of the Pratt Institute, Brooklyn, N. Y., who reports as follows:

"The supply of oil which is available for fuel in the United States, therefore, is, first, the small percentage (probably not over

2 or 3 per cent.) of the total production of the Pennsylvania and Ohio oil—the residuum from the process of refining; second, crude oil from the Ohio and Indiana fields, wherever the price of coal makes the burning of oil at 95 cents or $1 per barrel (plus freight) profitable; third, those portions of the California oil which are not best suited for refining; fourth, practically the entire output of the Texas field."

The demands for the better grades of oil for refining purposes will probably keep pace with the production; consequently we can never expect to see such grades of oil compete with coal to any large extent.

On the other hand, the refining value of the Texas oil and much of the California oil is so low that its value will probably always be largely controlled by the demand for it for fuel purposes. It is inconceivable that a fuel which has so many distinct advantages, and which is not unlimited in its supply, should sell in all markets at a price which would make it cheaper to burn than coal. Any great demand for such a fuel would bring its price up at once.

On the other hand, so long as there is an assured supply of Texas and California fuel oil, the price of such oil, that has little intrinsic value for refining will probably remain low enough to enable it to compete successfully with coal in those regions where coal is scarce in quantity and poor in quality. And the area in which this condition exists is sufficiently wide to create a demand for the fuel oil that will soon equal the supply, unless further stores of oil are found as the demand for it increases.

The fact should be remembered that in every oil region there is with each succeeding year a progressive proportionate increase in the percentage of the yield consumed for illuminating purposes.

ECONOMICAL ADVANTAGES OF AN OIL-FUEL INSTALLATION.

The relative evaporative efficiency of oil and coal as a fuel, as determined by this extended series of comparative experiments, is practically in the proportion of 15 to 10. The actual superiority of oil will be considerably greater, for in the coal experi-

ments unusual skill was exercised in the management of the fires. Lump coal of superior quality was used; and as the tests with coal were of comparatively short duration, the resulting loss from cleaning fires was much less than would occur in actual service. The oil experiments, however, were carried on under conditions that more closely approximated those that could be secured on board the sea-going vessel. The actual evaporative efficiency of a pound of oil as compared with a pound of coal will therefore be in the ratio of 17 to 10, and these figures can be regarded as substantially correct.

It will be found, practically, that the thermal efficiency of a pound of oil is the same whether the oil be crude or refined. While the crude oils contain sulphur and other chemical elements that are low in thermal efficiency, they contain substances that are particularly rich in hydrogen. In the process of distillation not only the sulphur but the rich hydrocarbons are lost, and it can thus be expected that, in the commercial burning of oil as a fuel, the evaporative efficiency of the same weight of oil fuel from every field or district will be practically the same.

From the standpoint of volume, therefore, it will be found that the highest evaporative results ought to be secured from the heaviest oil. As oil is sold by the gallon, and therefore by volume, the California product from the fuel standpoint ought thus to have an advantage over the yield from other fields. For some time, however, it can be expected that extra trouble and expense will be incurred in efficiently and uniformly burning heavy oils. There is not likely to be any actual advantage, therefore, from the use of heavy oils as viewed from the standpoint of weight of fuel.

Special experiments should be conducted to determine the best means of burning the heaviest of oils. The first distillation, however mild, is of great advantage in adopting crude petroleum as a fuel, since such slight refining not only reduces the explosive qualities of the oil, but materially decreases any liability of the oil to affect bunker or boiler plates injuriously. The solution of the problems of cost, as well as of transportation, will likewise be greatly aided by effecting this refining as near as possible

to the wells. It would certainly seem that the refinery should not be placed beyond the end of the pipe line or terminal marine shipping point.

In noting the comparative economical efficiency, for naval purposes, of oil and coal, there must also be taken into consideration the fact that a ton of oil can be stowed in somewhat less space than a ton of bituminous coal. Then, again, it must be considered that in the carrying of oil the compartments can be more completely filled. The relative efficiency of oil and good steaming coal, from the naval standpoint of fuel supply in warships, may thus be regarded as in the ratio of 18 to 10.

The Board is therefore of the opinion, after special investigation of the comparative merits of coal and oil, that, in regard to the evaporative efficiency, a long ton of the best quality of coal, such as Cardiff or Pocahontas, is equivalent to four and one-half barrels of oil; and that in a long ton of an inferior quality of coal the evaporative effect will be that obtained from only three to three and-a-half barrels of oil. This comparison is based upon the assumption that, until greater volume is permissible for the installation of naval boilers, it will not be possible to secure, in actual naval practice, an evaporation from and at 212 degrees Fahrenheit of over 14 pounds of water per pound of oil fuel. Increased efficiency, however, may be secured by heating the air requisite for combustion, as in the Howden or some similar system, whereby the heat of the escaping gases is utilized for raising the temperature of the entering air requisite for combustion.

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QUESTION OF FUEL SUPPLY ONLY ONE REMOVE IN IMPORTANCE FROM THAT OF FOOD SUPPLY AS REGARDS OUR ACTUAL NAVAL STRENGTH.

Through a combination of favorable circumstances the steam Navy of the United States has never been menaced by the fear of a coal famine. As a matter of fact, neither in the civil war nor in the Spanish-American war were the operations of the Navy of the United States interfered with by a substantial opposing force, and thus the blockades of the South Atlantic and Gulf States, as well as of the Cuban ports, were carried on with the

blockading vessels using a minimum amount of coal. There was practically no interruption to the delivery of fuel to any of our fleets during either the civil or Spanish-American wars, and therefore the fuel problem in the conduct of our naval operations has never been accorded the importance that it deserves.

By reason of our acquisition of the Philippines and Hawaiian Islands, as well as by reason of the future responsibility of defending the projected isthmian canal, the scene of our probable future naval operations will be at points less favorable to the United States than has existed in the past. It may be in the Pacific rather than on the Atlantic where our greatest naval battles of the future will be fought. In measuring our naval strength upon that ocean it must ever be kept in mind that the only coal mined in California, Oregon or Washington is of inferior quality, and that both the Australian and Japanese fuels are far superior to that mined anywhere on the Pacific coast of the American continent.

Practically the only coal, therefore, fit for naval purposes found in countries bordering on the Pacific Ocean is mined outside the United States, and thus the defense of the Hawaiian Islands, if not of certain portions of the California coast, may be greatly dependent upon our ability to use for emergency purposes California oil as a fuel in our ships of war. In consideration of this fact, the Board is of the opinion that at least one vessel cruising on the Pacific coast should be so arranged as to burn liquid fuel exclusively, and this vessel should be assigned to special experimental work of this nature for an extended period. There should be no attempt to use crude oil as an auxiliary fuel in this coast-defense vessel, but the effort should be boldly made to compel such vessel to rely exclusively upon the oil product.

It will undoubtedly cost considerable money to structurally adapt a war vessel for safely holding a large supply of oil, but the future military necessities of the Pacific coast seem to demand that the experiment should be made. There would be commercial, maritime and naval advantages accruing by the Navy Department engaging in this work, and one or two years' experiment along this line would be of incalculable benefit in showing

to the Navy the military possibilities of utilizing the oil-fuel supply of the Pacific coast for naval purposes.

AN OIL-FUEL INSTALLATION SHOULD BE EFFECTED IN ONE OF THE COAST-DEFENSE MONITORS OF THE PACIFIC SQUADRON.

It is highly probable, unless greater importance is attached to the value of the factors of evaporative efficiency, boiler capacity, steaming radius and character of fuel supply, that the successful and exclusive use of oil on board an armored cruiser or battleship cannot be brought about for some years. When the time comes that the consumption of coal will be jealously guarded in some such degree as the expenditure of ammunition, then will the expense and difficulty attendant upon the introduction of liquid fuel on board the warship be recognized in its fullness by naval experts.

For coast-defense vessels, particularly on the Pacific coast, an oil-fuel installation ought to be more easily secured. It is in this direction that practical tests should be made. In case an oil depot were established at Honolulu and one of the coast-defense monitors assigned to the training of men for the engineers' force, it might be possible to effect an oil-fuel installation in one of these monitors whereby the advantages and disadvantages of oil as a fuel for naval purposes could be absolutely ascertained.

In order to secure actual information in regard to the relative merits of various boiler installations, the British Admiralty has placed the services of several warships at the disposal of a naval boiler commission. The liquid-fuel problem is of such military importance to the United States Navy that it is not an unreasonable request which asks that one coast defense vessel on the Pacific coast be immediately fitted for exclusively burning liquid fuel. In addition to the practical benefits that would accrue from carrying on extended oil-fuel experiments in a cruising vessel, the moral effect of initiating such an advance would be an inspiration to all interested in having the Navy Department utilize the immense oil resources that are found on the coast of the Pacific.

AN OIL INSTALLATION SHOULD LIKEWISE BE INSTALLED IN SEVERAL TORPEDO BOATS.

The information and data already secured warrants the immediate installation of oil-fuel appliances on several torpedo boats and torpedo-boat destroyers, to test the adaptability of the water-tube boilers of bent-tube type for using this fuel. The installation should be effected on boats of similar character, so that an earnest but friendly rivalry would be created between the crews of the several vessels. There will come development and success by boldly equipping several boats with different types of installation. The morale of the torpedo-boat flotilla can be strengthened in no better way than by experimenting along this line.

In all probability but one or two of the bent-tube types of boilers fitted in our torpedo boats or destroyers will burn oil efficiently, unless extensive baffling is resorted to in the boilers so as to more efficiently direct the products of combustion among the tubes. Extended tests should be made with torpedo boats to find out the best means of securing an effective baffling, for the information secured will undoubtedly suggest important improvements as regards boiler management and design in the boilers of battleships.

* * * *

EXPERIMENTAL ENGINEERING RESEARCH WORK OF INESTIMABLE VALUE TO JUNIOR OFFICERS ASSISTING IN THE TESTS.

The naval demands of the future make it compulsory immediately to begin the training of engineering specialists. The result of these tests show that one of the most effective ways of developing such experts would be to organize a permanent engineering experimental board, whose special province it should be to conduct tests to determine the value of all appliances designed and submitted for use in the naval service. Junior officers of the Line having aptitude and inclination for such work should be detailed as assistants to this board.

Such research work would necessarily be of both theoretical and practical character, and there would therefore be secured upon the part of young officers detailed for such duty progressive

professional advance that would eventually fit them for important technical duty. These assistants should be ordered to accompany various naval technical boards on all journeys of inspection, so that they could assist not only in determining the capabilities and efficiencies of the appliances under observation and test, but would have an opportunity to observe the character of the organization and the methods of administration of great industrial plants.

The information secured by members of the Liquid Fuel Board in their visits to various steamers and industrial establishments where oil was used as a fuel was of inestimable value in extending the character of the oil-fuel experiments. The good of the service would have been greatly subserved, however, if a considerable number of young officers had accompanied the Board on every inspection tour, and thus had been brought in touch with many of the ablest of the oil-fuel experts in charge of great power plants.

It is undeniably the fact, paradoxical as it may seem, that the larger the technical board appointed to investigate a technical matter, the more knowledge of the subject will each individual member acquire. Where there is an earnest, spirited rivalry upon the part of various individuals to strengthen their position upon debatable points it can be expected that those holding divergent views will ever be on the lookout for special information to maintain their opinion. The final report thus submitted by a Board of considerable membership would, in general, be more comprehensive and valuable and command more respect than any report based on the views of a single expert.

The best interests of the service would be attained by having junior officers appointed to associate membership on every important board, for thus there would always be on the active list some officer who would have knowledge of many facts in connection with the investigation of naval matters that were not recorded in official reports.

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NOTES FROM ABROAD.

By Commander Walter F. Worthington, U. S. Navy, Member.

The writer, recently having had occasion to travel in two of the fast Atlantic liners, visiting several of the shipyards on the Clyde, the birthplace of marine engines as well as most of the important improvements in the same, meeting chief engineers, ship owners, ship builders and inventors, jotted down these notes on items of interest for his own use. At the suggestion of the Secretary-Treasurer of the American Society of Naval Engineers these random comments are offered to the members, hoping they may prove of some interest.

On one of the ships the routine is as follows: Reaching Liverpool Saturday morning, the company's agent comes on board at once to find out what stores are wanted. These he gets from the company's storehouse and delivers them on board Tuesday morning. The Chief Engineer has no anxiety concerning the stores, and has but to give the agent a list of what he wants, not being required to expend time and energy in following up requisitions. The company supplies whatever is asked for, but the presumption is that the Chief Engineer would lose his place if he abused this privilege.

The cylinders are opened and oiled.

On the same afternoon the boilers are blown down with the surface blow to the bottom of the glass, the steam pressure having been reduced previously to 60 pounds from the working pressure of 160 pounds. The boilers then stand until Sunday night, when they are pumped out. Monday they are opened and cleaned, Tuesday they are closed and filled with 50 tons of fresh water each and 10 pounds of soda ash (equal in strength to 14.8 pounds sal-soda).

Saturday and Sunday are utilized for cleaning.

The whole of Monday and the forenoon of Tuesday are devoted to overhauling, in which the whole engineer's force assists.

Tuesday noon the most of the firemen and coal passers are paid off, and they then have leave of absence until the following Saturday, when they rejoin.

The ship sails Saturday, late in the afternoon.

The engineers and oilers remain to work with the shore gang which comes on board to do all the necessary overhauling, and get leave only when their services can be spared. Each assistant engineer gets one day off every two weeks; one week's leave each summer and an additional week each winter.

During the week in port, in addition to the necessary repairs and adjustments, occasion is taken to make the routine examinations of the machinery as required by the surveyors. Part of this is done each voyage, the work being so divided that the whole will be completed within the limit of time allowed.

The owners of the vessel in question are extremely careful to avoid breakdowns or stoppages at sea, and it is stated that this vessel has not stopped at sea once through accident to machinery in the past six years; has made a voyage at full speed every other week, stopping one week in port at the end of each trip across and being laid up one to two months each winter.

After a crank shaft or a section of line shaft has been in use eight years it is considered unreliable and is replaced by a new one. This process goes on continually, the working gang being so expert that they can remove and replace a section of shafting during a week's stay in port. The tail shafts, of course, must be renewed while in dock, when the ship is laid up during the winter.

The boiler braces are protected by painting with a mixture of white zinc and paraffine of the grade used in England as lamp oil. Two coats are applied, allowing the first to dry before applying the second. The same is used with good results for painting the interior of evaporator shells.

Zinc is used in the boilers, though it has been found that a smaller quantity is required since the use of soda was begun.

The boiler tubes of this vessel have been in use ten years and are still good with the exception of a few tubes. The condenser tubes have also lasted ten years and are still good. Another vessel of the same line has been in constant use for twenty years without a complete retubing of her boilers, although a number of tubes have been renewed from time to time. This latter vessel has no evaporator and uses sea water for her make-up feed. No soda was used until about two years ago.

The main feed pump works from the main engines.

Preparatory to sailing, the bottoms of the cylinders are painted with white zinc mixed with paraffine. This does not readily turn yellow and can be scraped off easily when repainting is required. The tops of the cylinders are painted with a mixture of soda in water with a little Bath brick powder added, instead of using white lead and tallow. It withstands the action of sea water, looks white and can be wiped off readily on arrival in port, leaving the metal bright and clean.

The "United States" metallic packing is used for the main piston rods as well as for valve stems and other smaller rods, and even for the piston rods of the compressor for the ammonia ice machine. Before the introduction of this packing the piston rods of the main engine wore so badly that they had to be renewed every two or three years.

On this and several steamers visited by the writer the regular practice is to have the line shaft bearings lubricated by grease cups.

On the ship in question it is the practice, after having filled the boilers with the mixture of 50 tons of water and 10 pounds soda ash each, to allow this to stand twenty-four hours. It is then tested with a simple apparatus, of German invention, constructed on the same principle as the apparatus furnished by the Babcock & Wilcox Co. for use with their boilers. Enough soda ash is then added to bring the density up to one ounce of soda per ton of water. When at sea, and when the engines are developing about 28,000 I.H.P., 75 pounds of soda ash are used each twenty-four hours. The 75 pounds of soda ash are mixed with water and put into a tank, from which the solution is allowed to drip

into the feed tank at such a rate that the whole is used by the expiration of the time.

The surface blow is used once in twenty-four hours in each boiler, blowing down about 1½ inches in the glass, the boiler pressure being 160 pounds. The apparatus used for testing the alkalinity of the water also serves to show whether or not there is any oil in the water. Blowing is omitted, of course, should no oil be present.

Each watch cleans one-half of its fires immediately upon coming on watch, the other half being cleaned as soon as the first half has burned up brightly. Ashes are hoisted by the watch on duty at the middle and again at the end of the watch.

The firing on this and on a number of other merchant vessels visited by the writer, and which are run under natural draft, is no better than is found in the Navy. In fact these ships could never maintain their high speed if it were not for the ample grate surface provided by the designers.

The firing has been uniformly good on all merchant ships which the writer has seen running under artificial draft. It appears practically impossible for the average fireman continually to readjust the thickness of his fires to keep them right to suit a draft of air that is frequently changing in strength as the wind changes in force and direction, which occurs several times per day on the North Atlantic. On one ship dense black smoke came out of the after smoke pipe continually while very much lighter smoke came out of the forward pipe, indicating loss of heat from insufficient air aft and loss of heat from excess of air forward. Also the smoke was much denser at some times than at others, whereas with artificial draft a steady stream of uniform density is always seen.

The firemen get a lunch of bread and tea before going on duty at four P. M., a heavy supper when they come off duty at eight P. M. They also have a meat stew which they cook in the fireroom and eat when they come off duty at midnight and at 4 A. M.

The firemen are not required to keep any account of the amount of coal they use. Chief Engineers are agreed that such

an account as they might keep would be of no value. After the ship has been at sea for two or three days an estimate is made of the bunkers. If, on account of head winds or for any other reason, the coal is found to be disappearing too fast, the number of revolutions of the engines is reduced by cutting off steam shorter in the H.P. cylinders. The amount of coal carried is just about sufficient for the voyage at normal speed, with a margin for safety.

The "Patent Log" is put over only occasionally, and is not towed all the way across. The Captain checks his observations by the revolutions of the main engines, which are reported to him every twelve hours for that purpose. Thus the errors in coal account and in the records of the patent log, which cause naval officers so much unnecessary fret and worry, are summarily disposed of.

As the ship slows down to enter port a detergent is fed into the condensers and the latter allowed to get hot, losing the vacuum to a certain extent decided upon by experience. The main feed pump is stopped, and the black, greasy water delivered by the air pump into the feed tank is pumped overboard. Sponges and felt are used in the feed tanks. After the first twenty-four hours the sponges are found to be of but little use and the felt is little better.

At the shipyards on the Clyde much interest is being manifested in the marine steam turbine. One shipbuilder said to the writer that he considered that the marine steam turbine had long since passed the experimental stage. He then proceeded to point out new machines that he was installing for special work in marine turbine engines, five medium-sized vessels on the stocks in which he was about to fit such engines, one in the water just receiving her machinery, and one which had just completed her trial trip, making seven in all. One of the vessels was to cruise as far as New Zealand. When the suggestion was made that there might be a risk in sending such comparatively untried engines so far from home, he stated that his firm guaranteed the results. He stated that turbine engines effected a large saving in weight *if properly designed*, and that they also save somewhat

in overhead space and a little in length, though not much in breadth.

With regard to steering gear the general practice on the Clyde appeared to be to rely on the telemotor altogether and with no installation of the wire-rope gear. Considering the frequency of the failures of the wire rope gears of our naval installations to act surely and properly, it would seem to be an excellent plan for our constructors to follow the Scotch builders.

No visitor to the Clyde can afford to miss the opportunity of taking a trip on one of the new turbine steamers. Through the courtesy of the owners the writer was given the privilege of spending a day in the engine rooms and firerooms of the *Queen* while the vessel was under way, and of having his numerous questions answered by the chief engineer.

The *Queen Alexandra* has been described so often in the pages of this JOURNAL, as well as elsewhere, that it is hardly necessary to say that she is the newer and the faster of the new turbine steamers built by Denny & Bros., of Dumbarton, in 1902, to run on the Clyde from Greenock to Campbelltown during the summer months, touching at a number of points *en route*, going and returning.

Her trial speed was 21¾ knots; length, 270 feet; breadth, molded, 32 feet; depth to promenade deck, 18 feet 7 inches. She is fitted to accommodate 2,000 passengers.

To make her schedule time she steamed on this occasion at a speed of about 19 knots, and, notwithstanding the stops at five piers, reached Campbelltown on time to a minute, having left Greenock at 8.45 A. M. and having reached her destination at 12.30 P. M.

The H.P. turbine drives the center shaft at about 600 revolutions; the two L.P. turbines, one on each side, run at 800 revolutions for 19¼ knots speed. There is but one screw on each shaft. The aggregate I.H.P. developed is 3,000 and the boiler pressure is limited to 150 pounds.

Her owners have stated that the coal consumption is much less than that of a similar vessel fitted with triple-expansion engines, which they previously operated on the same service.

The oil consumption is almost nothing, as the same oil is used over and over again; the total loss in three summers of about eighteen months' running having been but one gallon.

The shafts when carefully gauged showed a wear of only $\frac{1}{1000}$ of an inch the first summer and nothing the second summer. The tool marks still remain in the thrust collars. Metallic packing is used for all stuffing boxes. "Pope's Joint" is used for all steam and exhaust pipes. This consists essentially in faced flanges, scraped to fit and brought together under great pressure by a special contrivance.

The lubricating oil for the main engine journals is forced into them under a pressure of about five pounds, works through the journal, and is then drained off into a settling tank. A special pump draws it up again and forces it into the circulation. The journals are kept cool by a water jacket through which sea water is forced by a pump, the water being then delivered overboard.

There is one main condenser on each side of the engine room close to its own low-pressure cylinder. The air pumps, two in number, are of the Edwards type without valves in the bucket, and maintain a vacuum of from 27 to 28 inches.

No bilge pump is used as no water finds its way from the machinery to the bilges. All the steam exhaust from every auxiliary machine is used in the feed heater, keeping the feed water up to 200 degrees Fahrenheit. The design of the feed heaters is such that the feed water travels three times through the heaters.

The forced-draft blowers are placed close to the working platform together with the air-pressure gauges, all of which are tended by the Engineer on watch, who maintains a steady pressure of one-half inch of water in the closed firerooms while under way. The blowers are large for the work required of them and run at a very low speed.

The main feed pump is fitted with the automatic arrangement usual on British vessels for regulating the speed of the pump according to the amount of water in the feed tank.

The stopping, backing and maneuvering of the engines was done quite as quickly and easily as could have been done with

triple-expansion engines, all of the signals being answered promptly.

The vacuum being constant, the speed called for was determined by the pressure shown on the gauge attached to the H.P. valve chest, so that when, at any time, the Captain signalled "half speed," for example, he always got the same number of revolutions and there was no delay or mistake due to attempting to count revolutions. The engines were run entirely by the pressures indicated on the gauges. A dial and pointer were connected with each main engine shaft so that the direction and speed of the shaft could be observed if desired. In fact, that was the only way that one standing a short distance from the engines could know whether or not the engines were in use, as they made no noise whatever, and there was no sound of rushing steam, such as is heard in other engines.

The work in the fireroom was perfect. Upon entering a fireroom a white light was seen to shine out from all the ash pits and from every one of the air holes in the furnace doors and fronts. Upon looking into the furnaces each was seen to have a layer of coal of the same depth, about five inches thick and perfectly level from front to back. One fireman appeared to handle four fires without excessive labor. The draft being sufficient and constant, his work consisted almost entirely in putting on coal. The fires were cleaned at night. The work of the firemen was rendered even more than usually easy by the fact that the length of grates in the furnaces was only five feet.

Without going into the details of the question of the relative economy of the triple-expansion and turbine engines, there is no doubt in the mind of the writer that a fair share of the economy claimed for this particular vessel is due to the perfection with which the details of the installation have been designed and carried out. With such regularity of firing, a high feed-water temperature, no steam leaks anywhere, no bilge pump, and very efficient types of air pumps, feed pumps and feed heaters, any plant would show exceptional results.

As before stated, the signals from deck were answered promptly. There appeared to be, however, some slight deficiency in the

backing powers, as the speed of the vessel was reduced (the revolutions of the turbines were reduced) some time before reaching the pier. At some of the piers it was difficult to get alongside, on account of their situation and also because of the direction of the wind, which was blowing strongly at the time. On the whole, the boat appeared to handle as well as the average of our river and bay steamers.

The inventor of these turbines states that the backing power of the newer vessels of the *Queen Alexandra* class will be much increased, since it is found quite practicable to give a considerably larger area to the L.P. screws without reducing their efficiency when going ahead.

During a visit to Wallsend-on-Tyne the writer had the pleasure of being shown through the Turbinia Works, where marine steam turbines are made, the inventor, the Hon. C. A. Parsons, himself, sparing his valuable time to act as guide. Turbines were seen in every stage of construction, and among them a set developing 10,000 I.H.P. and destined for installation on an Atlantic liner. The total number of marine turbine installations which have been built or which are being built in these works encompass the outfit for twenty-eight vessels, although the advantages of turbines was first demonstrated by the little *Turbinia* in 1897.

In conclusion, it may be said that, after reading much of what has been written both for and against the Parsons' Marine Turbine, after many conversations with shipbuilders and others, and after seeing the turbine in operation, the writer is strongly inclined to believe that some form of turbine engine will soon be universally installed for all merchant vessels of 15 knots speed and over, and of not less than 3,000 I.H.P.

The advantages of turbine engines for the propulsion of all classes of war vessels are not so obvious as for their use in merchant ships, for the reason that the former cruise so much at low speed. To accomplish this economically involves the addition of cruising turbines or triple-expansion reciprocating engines, with a corresponding increase in weight, space and complexity of the plant. Nevertheless, when we consider the length of time our small gunboats, torpedo-boat destroyers and torpedo

boats are laid up for repairs, and when we think how much longer the gunboats would be laid up if they were run frequently at high speed, which should be the practice if we expect to maintain efficiency in their material and personnel, and then consider a vessel fitted with turbine engines, which is not only theoretically but practically ready at all times to be run at any speed, and which is subject to almost no wear and tear, liable to no accident beyond the power of the force on board to repair, and even requiring no cleaning up on arrival in port, we cannot but feel that the time has come for us to follow the indication of the times and make a radical change at the earliest moment when opportunity offers in projected vessels of these types.

BALANCE CYLINDERS.

By Luther D. Lovekin, Associate.

The purpose of a balance cylinder is to neutralize the forces set up by a reciprocating body. It should be designed so that these forces meet equal and opposite forces in the balance cylinder instead of transmitting them in the shape of pressure to the crank shaft or whatever other means is used to give the reciprocating motion. A moment's consideration of this proposition will show its great importance and the wide range of its possibilities in the engineering world. It is a subject which has hitherto received little or no attention from scientific designers; in fact, the only field to which balance cylinders have been applied thus far is that of valve gears, and this so crudely that the so-called balance cylinders as we have known them are not balance cylinders at all, for they neglect the most important force developed by a reciprocating body. The most notable exception to this is the Improved Lovekin-Thom Assistant Cylinder, the theory of which was set forth in an article before the Society of Naval Architects and Marine Engineers, in New York, November, 1902.

Perhaps the following illustration will give a clear conception of the problem which confronts a true balance cylinder:

In Fig. 1, *W* is the reciprocating body moving between *A* and *B*. It is attached to one end of a spiral spring which is fixed at the other end. The position of the body with the spring at rest would be at *C*. When in the position *A* the spring is compressed and at *B* it is extended. The work expended in distorting the spring from its normal position is returned each time the body comes to the center. Suppose the inertia of the body to be great enough to carry it the rest of its stroke; then, if it were not for friction, the body would continue reciprocating back and forth between *A* and *B* without any outside assistance.

This is exactly the function of a true balance cylinder; it should act as a spring or dash pot at each end of the stroke. The energy expended in compression is returned in expansion, so that, theoretically, the reciprocating motion could continue indefinitely without consumption of steam or other outside source of power. This analogy holds good whatever the direction of the reciprocating motion. In the case of the spring, motion in a vertical direction would simply involve a change in adjustment so as to keep the travel between the same points. In a similar way a balance cylinder works just as perfectly on a vertical reciprocating weight by adjusting the bottom pressure so that it exceeds the top pressure by the right amount.

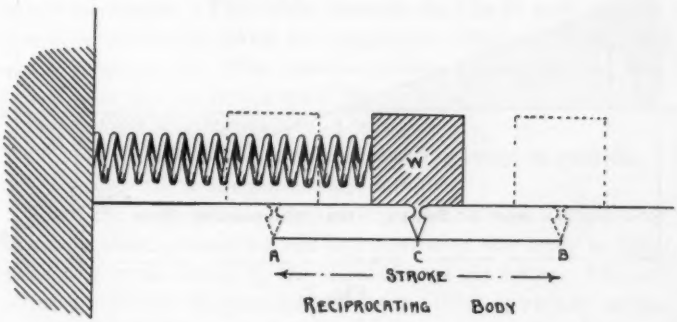


Fig. 1.

A little consideration of this principle will also bring out the crudeness of the usual type of so-called balance cylinders which relieve gravity only. The force of inertia increases with the square of the revolutions, and in modern engines this invariably exceeds the force of gravity. This applies very strongly to high-speed naval engines. For example, at 120 R.P.M. the maximum pressure due to inertia is over twice that due to gravity; hence the folly of counteracting the latter and neglecting the former. It is hard to see why this source of wear and loss of power does not receive more consideration from scientific designers.

There is one type of assistant cylinder on the market which

aims in some degree to counteract inertia as well as gravity, but it is very crude and unscientific in its action. It has an exhaust from each end of the cylinder, which, besides wasting steam, is absolutely unnecessary, as shown by the action required.

We will now consider the forces to be overcome in the case of a body which receives its reciprocating motion from a revolving crank. In order to eliminate gravity we will assume first that the motion is in a horizontal plane. We will also neglect friction, for this is a force which cannot be counterbalanced except by the expenditure of work.

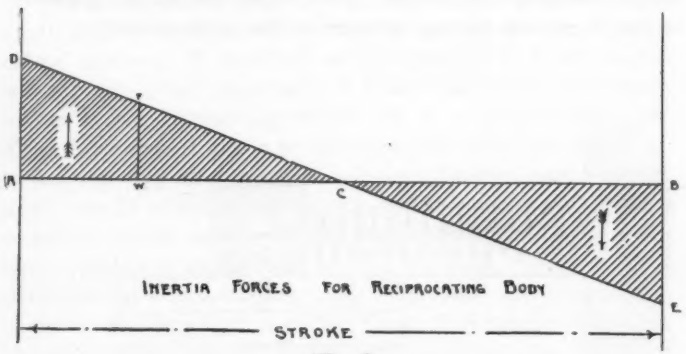


Fig. 2.

See Fig. 2. The body *G* moves back and forth between *A* and *B* so that *A B* represents the length of its stroke. Let us consider the forces developed during one stroke from *A* to *B*. It is stationary at *A* for an instant and requires a force to start it toward *B*. This force has to overcome the inertia of the body; it is a maximum at *A* and may be represented by *A D*. This force continues to act on the body with decreasing intensity till it reaches the center *C*, where it becomes zero. At this point the body has attained its maximum velocity and must be retarded toward *B*. To accomplish this a retarding force is required exactly equal in intensity but opposite in direction to the accelerating force required up to the point *C*. This retarding force also reaches its maximum at the end of the stroke, where the body is

brought to rest. We represent this force by $B\,E$ below the line $A\,B$; thus the triangles $A\,D\,C$ and $B\,E\,C$ represent the diagram of forces necessary to overcome the inertia of the body during its progress from A to B. The same diagram holds for the return from B to A, except that the former accelerating forces now become retarding forces and *vice versa*. Their direction of action remains unchanged and may be indicated by the arrows shown in Fig. 2. Thus at the position W when traveling toward B the accelerating force is represented by $W\,F$. When returning toward A the retarding force at the point W is also represented by $W\,F$ and acts in the same direction.

For purposes of calculation in actual design the diagram of these inertia forces is plotted from the formula developed in the article mentioned. This is the formula used in all such calculation of inertia forces where the angularity of the connecting rod is not considerable. The maximum force (represented in Fig. 2 by $A\,D$ or $B\,E$) $= .0003408\,rN^2W$,

where r = crank arm in feet,

W = weight of reciprocating body, in pounds,

N = revolutions per minute.

When the reciprocating motion is produced from a crank with relatively short connecting rod the motion of the body is influenced to a great extent by the angularity of the latter. This requires a modified diagram to express the force at various points of the stroke. The equation for the force at any point is represented by the equation $F = .0003408\,rN^2W\left(\cos\theta + \frac{\cos 2\theta}{n}\right)$, where θ is the angle made by the crank with the line of travel, n = ratio of connecting rod to crank, R, N and W as before. By this formula the line representing the forces throughout the stroke becomes a curve instead of a straight line, as shown in Fig. 2.

In the present discussion we will consider a balance cylinder design for a valve gear, which is the common application of the device. And in this case the ratio of the eccentric rod to the eccentricity is so great that we may neglect the angularity of the rod and work from the diagram first proposed. That is a straight

line, as in Fig. 2, where $A\,D$ is determined by the formula $F = .0003408\,rN^2W$.

We now have the forces presented in such form that a cylinder may be designed on scientific principles to balance the forces expected, and without such an analysis a systematic consideration of the forces developed is impossible.

The valve gear under consideration is vertical, which introduces the force of gravity into our problem, but this does not affect the inertia forces to be overcome, for they remain the same no matter what the direction of the reciprocating motion. We allow for the force of gravity simply by taking it as a component part of the downward forces considered in the balance cylinder. The downward force exerted within the cylinder itself is the total pressure of the steam on top of the piston. This we have under control, though of course the other component, that of gravity, is fixed and constant. The total downward force therefore consists of the weight of the gear plus the total pressure of steam on top of the piston. The upward force consists solely of the steam pressure under the piston.

We now have to arrange the forces at our disposal in such shape that they will neutralize as nearly as possible the inertia forces previously ascertained. This is done by means of a diagram, where the forces are plotted to the same scale as the inertia in Fig. 2. We start with the base line AB, Fig. 3, in which the length AB represents the length of the stroke or travel of valve, A being the top position and B the bottom position. On this base line we plot the total upward steam force, *i. e.*, the net area of piston multiplied by the pressure of the steam. We take the steam supply at such a pressure that the total force under the piston is represented by the line AC. We carry this pressure from C to D on the down stroke. At D the supply is cut off and compression begins as the piston continues its downward stroke. The pressure now rises in accordance with the well known law, $P\,V =$ constant. The volume is calculated so that the desired pressure is reached at the end of the stroke, and the total upward force there is represented by the line BE. On the return stroke the pressure at E is expanded down the line

ED in the same manner as it was compressed. Thus the line *CDE* represents the theoretical indicator card diagram for the bottom of the balance cylinder. In actual practice it is found that the expansion on the up stroke will not return exactly along the compression line of the down stroke. It falls below to an extent that depends upon the leakage and condensation in the cylinder.

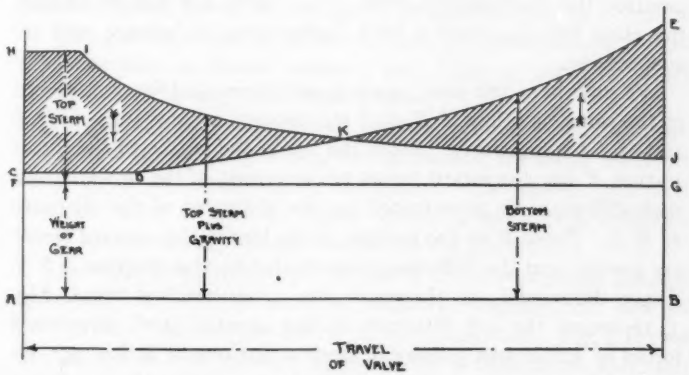


Fig. 3.

We turn now to the downward forces which oppose those represented by the line *CDE*. First, upon the same base line we construct the line *FG* at a distance above *AB* corresponding to the weight of the reciprocating parts. This is the fixed and constant component of the total downward force. The other component is the total steam pressure on the top of the piston. We will therefore plot this top steam pressure above the line *FG*, so that the total downward forces may be represented by the distance of the top steam line above the base line *AB*.

The top steam is received at the same pressure as the bottom steam, but the total pressure of the top steam will be slightly greater than that of the bottom, owing to deduction for rod area in the latter. It is represented by the line *HF*. This pressure continues along the down stroke to the point *I* where cut off occurs. From the point *I* the volume in the upper part of the

cylinder increases with the travel of the piston, and as it is no longer connected with the steam supply its pressure decreases. This expansion takes place along the line *IJ* to the point *J* at the bottom of the stroke. The process is reversed during the up stroke and the expanded steam at *J* is again compressed to the pressure *I* along the same line. Thus the line *HIJ* represents a theoretical indicator diagram for the top of the cylinder. In practice the compression from *J* to *I* does not follow exactly the same line, but runs a little higher, due to leakage and re-evaporation.

We now have the total upward and downward forces referred to the same base line *A B*, and represented by the lines *C D E* and *H I J* respectively. From the top of the stroke to the intersection *K* the downward forces are in excess of the upward, and their difference is represented by the ordinates of the diagram *H K C*. From *K* to the bottom of the stroke the upward forces are greater and the difference represented by the diagram *E K J*. These differences, as shown in the cross-hatched areas, Fig. 3, represent the net resultant of the upward and downward forces of steam and gravity. Their directions of action are indicated by the arrows and do not change, hence these are the forces available to overcome the inertia previously determined.

We may now take the inertia diagram in Fig. 2 and apply

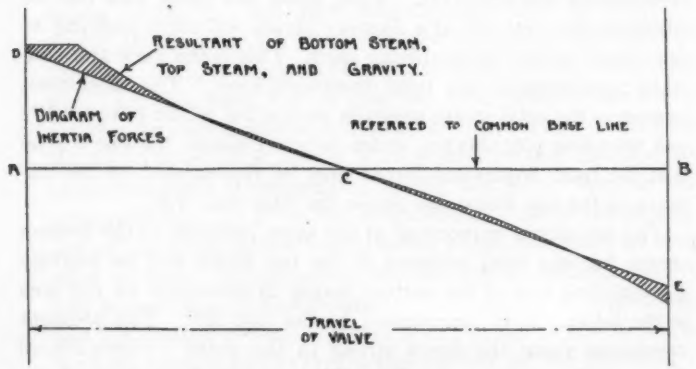


Fig. 4.

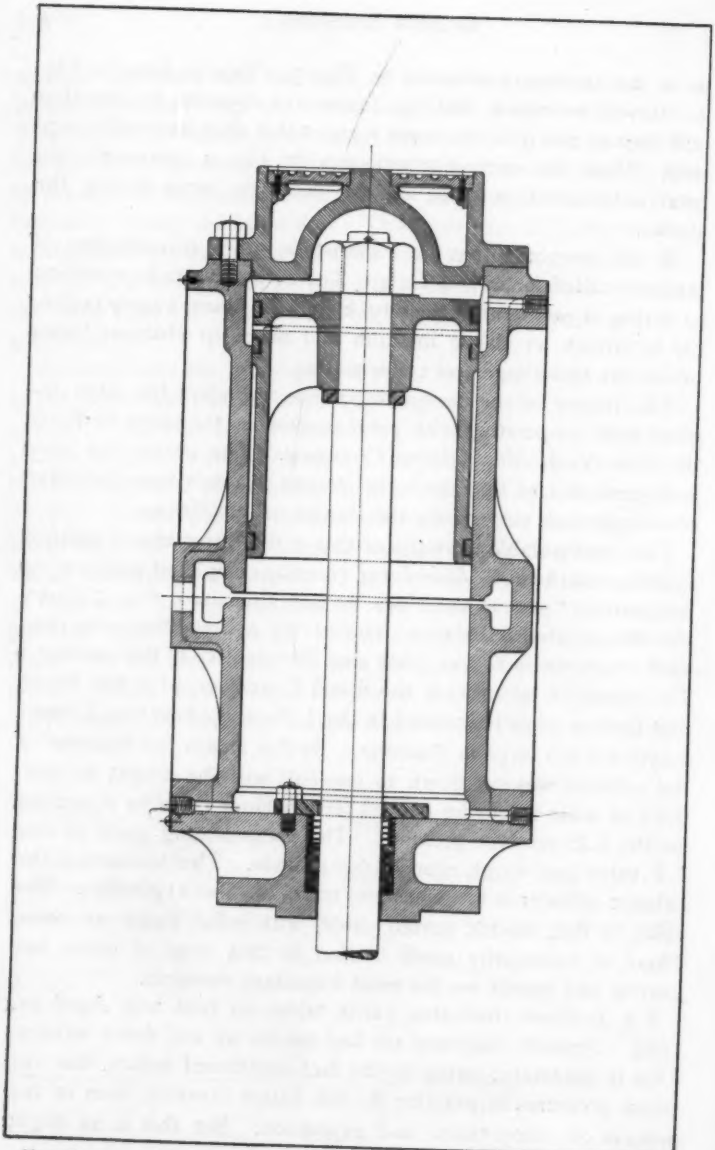
to it the resultants obtained in Fig. 3. This is done in Fig. 4. It will be noted that the forces are opposite in direction and vary so nearly in the same manner that they neutralize very well. Thus the cross-hatched area in Fig. 4 represents the total unbalanced pressure on the eccentric strap during the stroke.

It will be noted that no exhaust or other consumption of steam is called for in this design. The cylinder acts as a cushion or spring at each end of the stroke, and the steam supply is simply to furnish an elastic medium and make up whatever losses occur due to leakage and condensation.

This theory in the design of balance cylinders has been applied and is operating with great success in the ships built by the New York Shipbuilding Company. The design has now been perfected so that the actual results as taken from indicator cards approach very nearly the theoretical conditions.

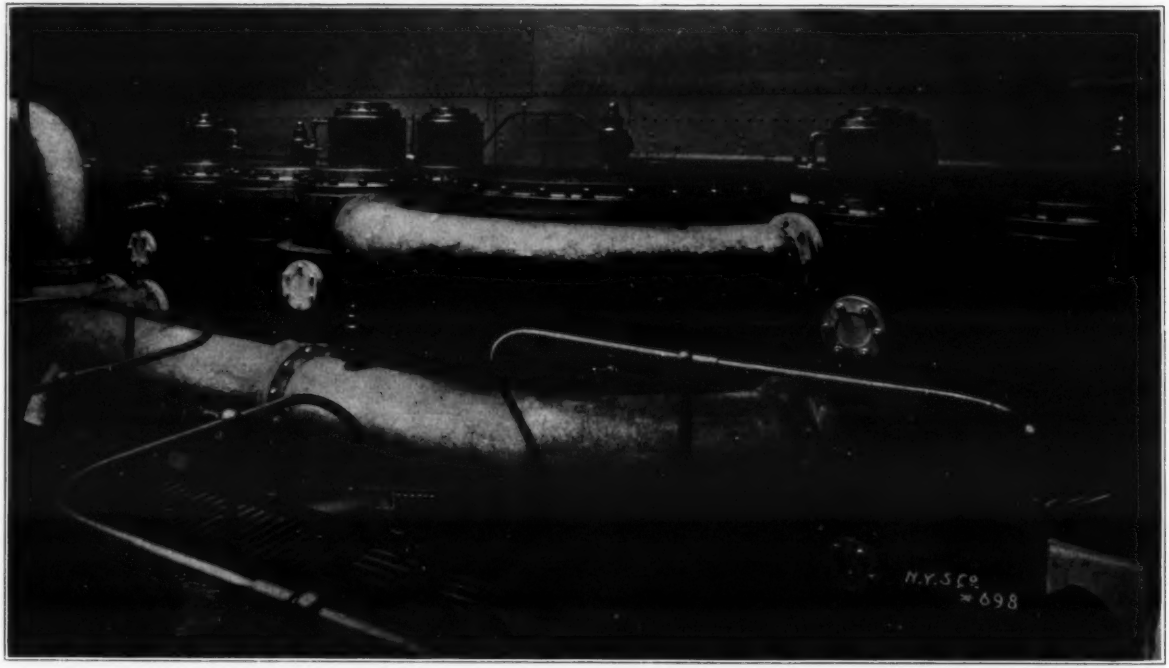
The most notable example of this is the low-pressure balance cylinders of the S. S. *Manchuria*, recently completed and now on her journey "around the Horn" to San Francisco. Fig. 5 shows the design of this balance cylinder for a theoretical diagram, such as shown in Fig. 4. [See also Frontispiece of this number.] The steam is taken from the first I.P. receiver, as it was found that the low pressure carried in the L.P. valve chest would entail a cylinder too large in diameter. By this means the diameter of the cylinder was cut down to one-half and the weight to one-third of what would be needed for a balance cylinder operating on the L.P. receiver pressure. The reciprocating parts of this L.P. valve gear weigh nearly 8,000 pounds. The diameter of the balance cylinder is 11 inches and travel of valve 11½ inches. The valve is flat, double ported, slide, with relief frame on back. There is necessarily some friction in this type of valve, but gravity and inertia are the most important elements.

Fig. 6 shows indicator cards taken on trial trip April 21, 1904. Separate diagrams are laid out for up and down strokes. This is necessary, owing to the fact mentioned before, that the steam pressures in practice do not follow identical lines in the process of compression and expansion. But this is so slight



THE LOVEKIN-THOM IMPROVED ASSISTANT CYLINDER AS FITTED ON S. S. "MANCHURIA".

Fig. 5.



ENGINE ROOM OF S. S. "TEXAN", SHOWING ASSISTANT CYLINDERS.

that the effect on the diagram is not serious. A study of these cards and the diagrams plotted from them will show how completely the forces of inertia and gravity are counterbalanced: 92½ per cent. is the proportion of the total forces that are neutralized by the action of this balance cylinder. The maximum pressure per square inch on the projected area of the eccentric strap amounts to just 11.3 pounds. Had this gear been fitted with an ordinary balance cylinder, and gravity balanced exactly, there would still have remained a pressure of about 54 pounds per square inch due to inertia.

These diagrams being plotted from actual conditions show beyond question the utility and efficiency of this type of balance cylinder. The effect noticed on other ships running with this device is that there is no heating due to friction and no wearing down of the gear, hence the valve setting remains constant. One record at hand is that of the S. S. *Texan*, which ran 60,000 miles without any necessity for lining up the valve gear.

Another point of advantage to be noted in this design of cylinder is that the pressure of the steam automatically adjusts itself to correspond with the revolutions per minute. It is a matter of general observation that receiver pressures vary nearly as the square of the revolutions, hence the suitability of receiver pressures for counterbalancing inertia at varying speeds. Cards taken and analyzed show a pressure on the eccentric strap which is nearly uniform throughout the stroke for all speeds. The balance is most perfect at the designed speed, but in no case does the variation approach that of an ordinary balance cylinder, even under the best condition of the latter. The ordinary balance cylinder does not counteract gravity except at one particular pressure in the receiver, and this lack of balance increases directly with the variation from that pressure.

These balance cylinders are to be applied to the armored cruiser *Washington* and the battleship *Kansas*, now building for the U. S. Navy. In these designs some interesting problems were encountered, as the inertia formed such a large proportion of the forces to be balanced. This necessitated a change in the form of the piston used, to produce compression on top as well

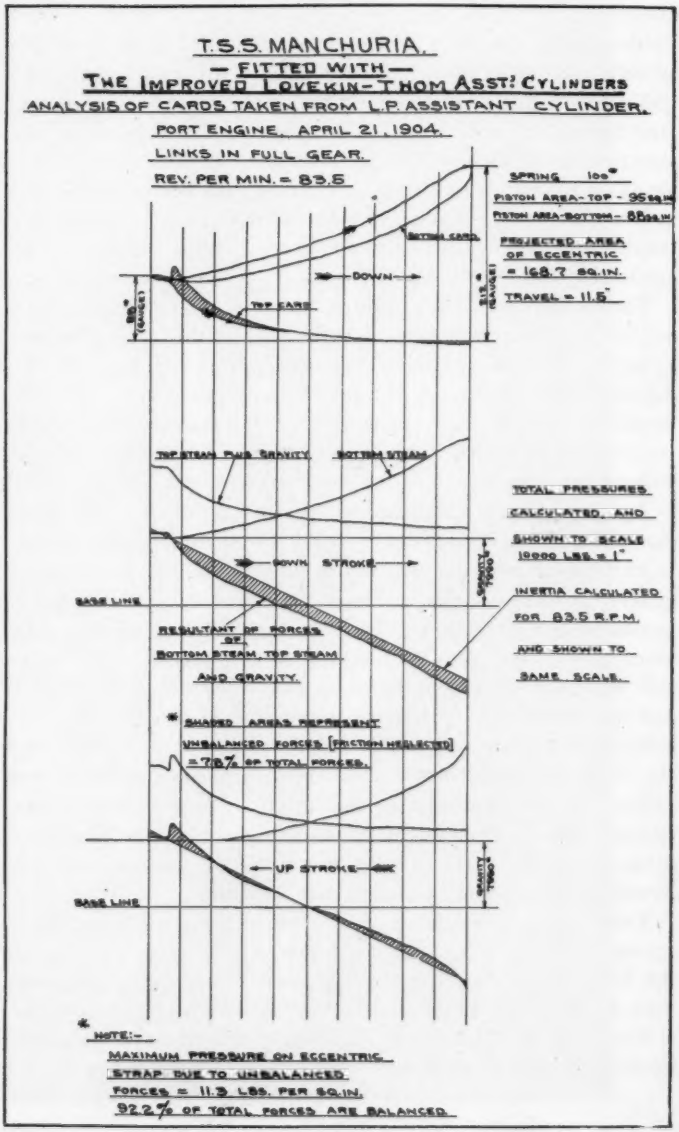
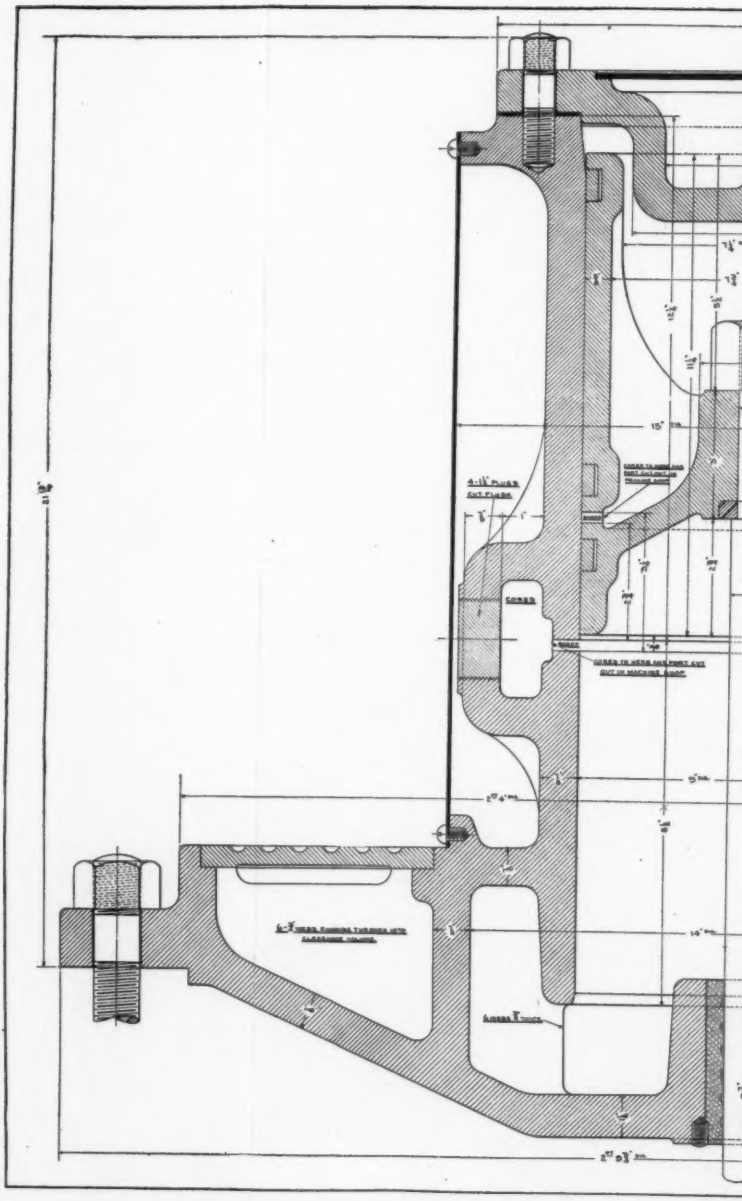

T.S.S. MANCHURIA.
— FITTED WITH —
THE IMPROVED LOVEKIN-THOM ASST? CYLINDERS
ANALYSIS OF CARDS TAKEN FROM L.P. ASSISTANT CYLINDER.
PORT ENGINE. APRIL 21. 1904.
LINKS IN FULL GEAR.
REV. PER MIN. = 83.5
SPRING 100#
PISTON AREA-TOP - 95 sq in
PISTON AREA-BOTTOM - 88.94 in
PROJECTED AREA OF ECCENTRIC = 168.7 SQ.IN.
TRAVEL = 11.5"
BOTTOM CARD
TOP CARD
DOWN
TOP STEAM PLUS GRAVITY
BOTTOM STEAM
TOTAL PRESSURES CALCULATED AND SHOWN TO SCALE 10000 LBS = 1"
DOWN STROKE
BASE LINE
INERTIA CALCULATED FOR 83.5 R.P.M. AND SHOWN TO SAME SCALE.
RESULTANT OF FORCES OF BOTTOM STEAM, TOP STEAM AND GRAVITY.
* SHADED AREAS REPRESENT UNBALANCED FORCES. [FRICTION NEGLECTED] = 7.8% OF TOTAL FORCES.
UP STROKE
BASE LINE
* NOTE:-
MAXIMUM PRESSURE ON ECCENTRIC STRAP DUE TO UNBALANCED FORCES = 11.3 LBS. PER SQ.IN.
92.2% OF TOTAL FORCES ARE BALANCED.

Fig. 6.

XU


4-1¼ DIAM.
CAST HOLES
CORED
CORED TO HERE AND POINT GIVE
CUT IN MACHINE SHOPS
CORED TO HERE AND POINT GIVE
CUT IN MACHINE SHOPS
ARMS T THICK

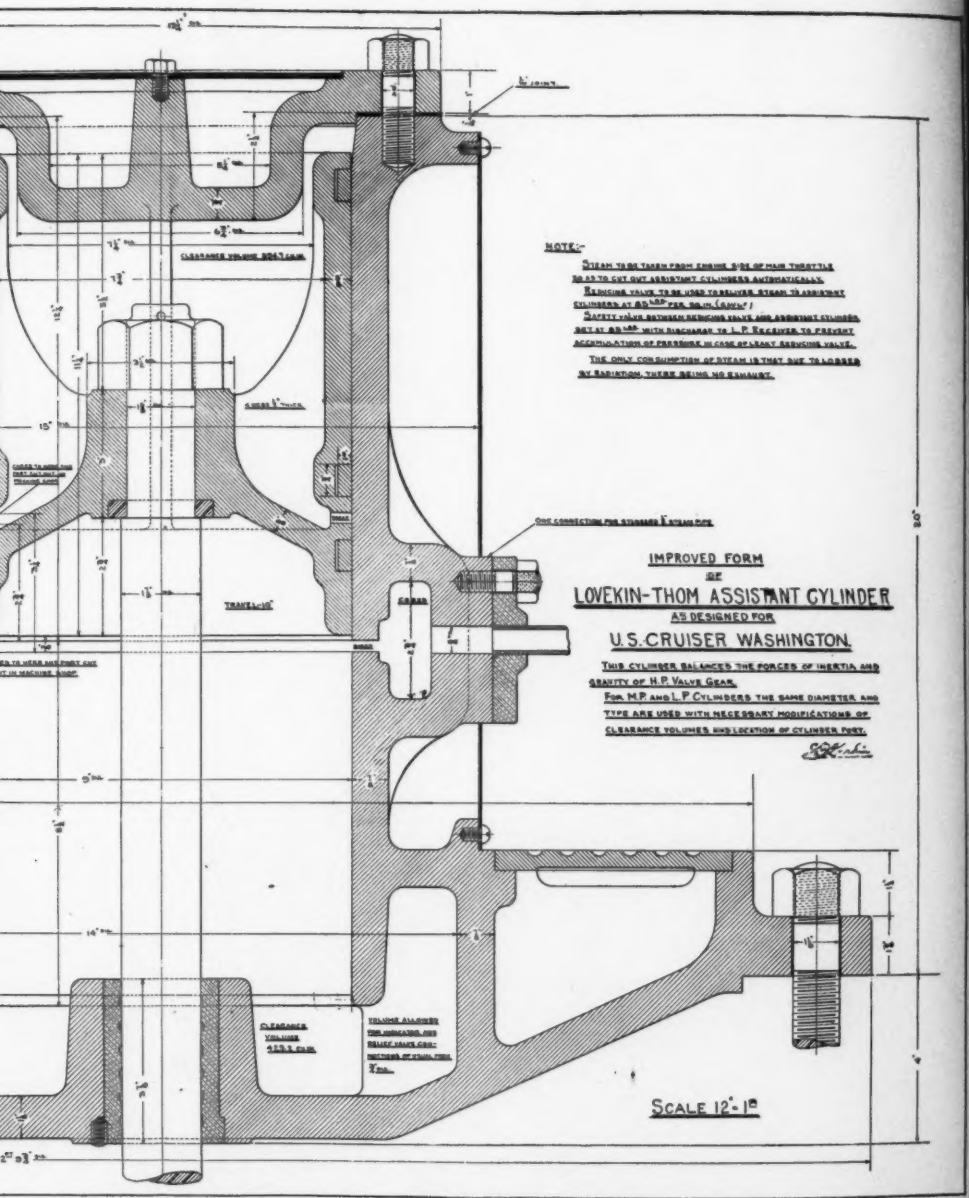

NOTE:-
STEAM TO BE TAKEN FROM ENGINE SIDE OF MAIN THROTTLE SO AS TO CUT OUT ASSISTANT CYLINDERS AUTOMATICALLY.
REDUCING VALVE TO BE USED TO REDUCE STEAM TO ASSISTANT CYLINDERS AT 80 LBS PER SQ.IN. (GAUGE).
SAFETY VALVE BETWEEN REDUCING VALVE AND ASSISTANT CYLINDERS SET AT 80 LBS WITH DISCHARGE TO L.P. RECEIVER TO PREVENT ACCUMULATION OF PRESSURE IN CASE OF LEAKY REDUCING VALVE.
THE ONLY CONSUMPTION OF STEAM IS THAT DUE TO LOSSES BY RADIATION, THERE BEING NO EXHAUST.
IMPROVED FORM
OF
LOVEKIN-THOM ASSISTANT CYLINDER
AS DESIGNED FOR
U.S. CRUISER WASHINGTON.
THIS CYLINDER BALANCES THE FORCES OF INERTIA AND GRAVITY OF H.P. VALVE GEAR.
FOR H.P. AND L.P. CYLINDERS THE SAME DIAMETER AND TYPE ARE USED WITH NECESSARY MODIFICATIONS OF CLEARANCE VOLUMES AND LOCATION OF CYLINDER PORT.
TRAVEL-10"
CLEARANCE VOLUME 423.3 CUB.
SCALE 12"-1"

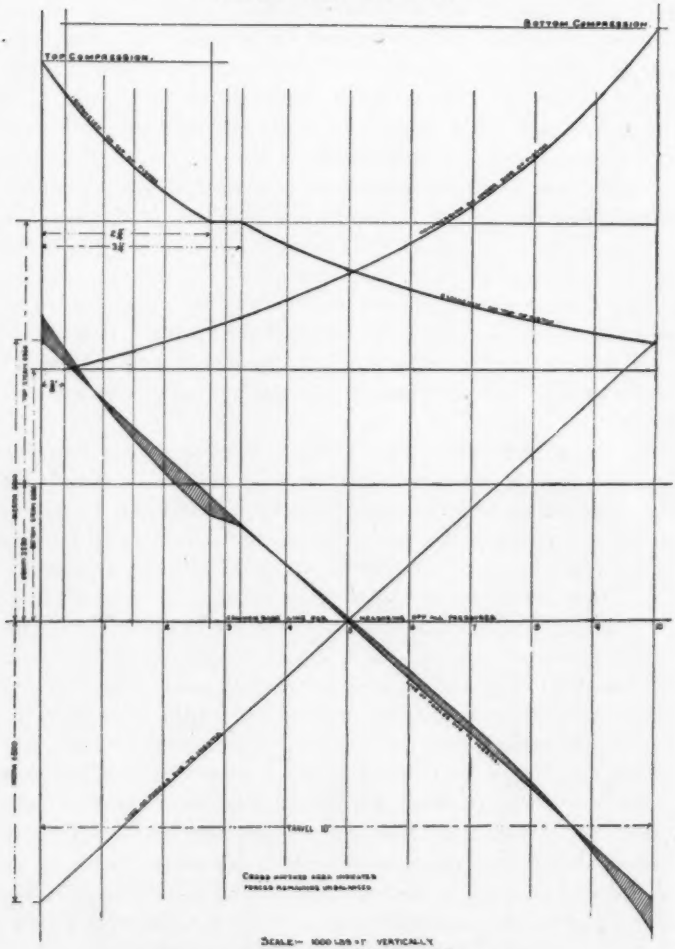
Fig. 7.

as on the bottom. The design adopted is shown in Fig. 7. The theoretical diagram from this cylinder is shown in Fig. 8. It will be seen from this diagram how perfectly the forces neutralize; in fact, the fulfilment of these theoretical conditions would bring about a balance so perfect that the heavy gears might be run by a thread. While the actual results cannot quite equal the theoretical diagrams shown, they will approach very closely, as proved in the case of the S. S. *Manchuria*.

This means a material reduction in power lost due to friction, with consequent saving of lubrication and fuel as well as labor in repairs and adjustment. On the cruiser *Washington* the reciprocating parts of the L.P. valve gears weigh over 5,000 pounds. At 120 revolutions per minute the inertia force reaches a maximum of 10,500 pounds at each end of the stroke. This shows how much more important is the latter element, hence it should really receive first attention when considering a balance cylinder.

A little consideration of the action of a scientific balance cylinder will suggest many uses for which it may be designed. It has been shown both theoretically and practically that the forces set up in a reciprocating body may be neutralized so far as pressure on the crank is concerned. It costs nothing to operate. Why, then, should it not be used on a larger scale to do away with the wear and friction that such pressure entails? It is by no means restricted to vertical valve gears aboard ship. There are thousands of reciprocating weights wearing away at their driving gears in all branches of the engineering world. Consider the high-speed engine valve gears alone. On some the inertia runs into large figures, and this explains the continued adjustment necessary to take up wear, not to mention the oil used to keep them cool. Both horizontal and vertical engines are subject to the same inertia pressures, which might just as well be borne by a properly designed balance cylinder. Other lines of engineering suggest other reciprocating weights which are hammering away at their bearings. Why not put a balance cylinder wherever a body reciprocates fast enough for the inertia to equal its weight? Steam is not necessarily the elastic body with which it may be

DIAGRAM OF IMPROVED LOVEKIN-THOM ASSISTANT CYLINDER AS DESIGNED FOR U. S. ARMORED CRUISER "WASHINGTON", HIGH-PRESSURE VALVE GEAR.



Top clearance = 4.633 linear inches = 294.7 cubic inches.
Bottom clearance = 7.053 linear inches = 429.2 cubic inches.
Diameter of cylinder = 9 inches, diameter of rod = 1¼ inches.
Pressure 85 pounds per gauge = 100 pounds absolute.

Fig. 8.

HIGH-PRESSURE VALVE GEAR, U. S. S. *WASHINGTON.*

	Pieces.	*Weight.*	*Gravity effect.*
Balance piston,	1	65	65
Valve,	1	1130	1130
Valve stem,	1	400	400
Link block,	1	130	130
Links and pins, set,	1	430	215
Suspension link,	1	90	90
Eccentric rod,	1	450	450
Eccentric strap,	1	845	845
	Totals,	3540	3325 (use 3330).

Maximum inertia $= .0003408\, rN^2 W = .0003408 \times .416 \times 120^2 \times 3330 = 6800$.

One balance cylinder, weight to be relieved, 3,330.

inertia to be relieved, 6,800.

Percentage of inertia relieved, by diagram, 91, (Gravity totally relieved.)

DIRECTIONS FOR USING DIAGRAM.

Calculate the "Gravity Load" and, from the "Common Base Line" lay this off upward, with a scale 1 inch = 1,000 pounds. This establishes the "Base Line for Measuring Load Additional to Gravity."

Calculate "Total Pressure of Bottom Steam," due to inlet pressure, and lay this off upward, at left of diagram, from the "Common Base Line." Now, from point of cut-off on under side of piston ($\frac{3}{8}$ inch as shown) construct the curve $PV =$ Constant, thus giving curve "Compression on Under Side of Piston."

The pressure on top of piston is measured upward from the "Base Line for Measuring Load Additional to Gravity," since gravity, being always a constant downward pressure, is added to the pressure on top of the piston, the sum of the two being the "Total Downward Pressure." In this diagram the steam in top of cylinder has been compressed during the up-stroke to a point as shown, and when the piston descends $2\frac{3}{4}$ inches of its travel the port in piston equalizes with steam at inlet pressure during the next $\frac{1}{4}$ inch of its descent; the connection with top is then cut off and the curve "Expansion on Top of Piston" is formed, assuming that $PV =$ Constant.

The reverse of each of these operations takes place on UP-STROKE, *i. e.*, the steam that has been compressed in the bottom of the cylinder expands on the up-stroke until the piston uncovers the port in cylinder, when a fresh equalization of steam takes place as shown. At the same time the steam in the top of the cylinder, which had before expanded, is now being compressed until a new equalization of steam is allowed for a short period, is then cut off, and further compressed as shown. The difference between these two steam forces and the "Gravity Load" at any point of the stroke is the force tending to overcome INERTIA, the "Lines of Forces Due to Inertia" being laid off as shown, above and below the "Common Base Line," to corresponding scale, and being a maximum at the ends of the stroke and zero at the point of crossing center, as would be expected.

Measuring these distances positively and negatively and plotting same above or below the "Common Base Line" at the various points of the stroke produces the irregular line shown beside the "Line of Forces Due to Inertia," the shaded area representing the only unbalanced load in terms of the adopted scale.

operated. In fact, air is superior in many respects. Even at atmospheric pressure it may be used in suitably designed cylinders. There is undoubtedly a large field for the development of this principle in other lines besides that of marine engineering.

In conclusion, the following summary is given of the advantages of properly designed "balance cylinders" for valve gears alone:

1. Increased I.H.P. of main engines, or a corresponding reduction in coal, or other fuel, due to decreased friction of valve gear.

2. Saving in oil, due to decreased friction of valve gear.

3. Reduction in weight and first cost of cylinder when used on low-pressure valve gears to replace old style balance cylinder.

4. Valve gear can be 25 per cent. lighter and still retain the safety of the heavier gears as ordinarily used.

5. All strains due to inertia and weight are removed from the crank shaft; thus smoother running of the engine is obtained.

6. Repair bills reduced to a minimum, the valve gear being free from pressure, and the wear and tear on all parts being insignificant.

7. Troublesome valve gears can be positively corrected by the application of such cylinders.

PROPELLER-BLADE INACCURACIES: PROPOSED METHOD OF MACHINING AND FINISHING.

By Lieutenant Commander W. Strother Smith, U. S. Navy, Member.

[The following was submitted to the Bureau of Steam Engineering in the form of an official report.]

Believing that, with an accurate finish of the driving face of a propeller blade to the true designed pitch, an increase of efficiency will be gained which will more than compensate for the increased expense, I have to submit the following argument, and a method of accomplishing the desired result by means of a machine which may be built at a moderate cost.

There are machines which are used for this purpose, especially the one now used at the Washington Navy Yard for making experimental wheels. The limit of this machine, however, is stated to be confined to propellers of twenty-seven inches in diameter, and to expand its effectiveness to compass those of eighteen feet and over, would be to render the size of this machine huge and unwieldy.

In "Engineering" (London) October 9, 1903, a description of the Bauer Propeller-Blade Shaping Machine is given. This is the invention of Dr. Bauer, the Chief Engineer of the Vulcan Works at Stettin.

The commercial importance of having true driving faces to large propellers has been recognized by such an authority as the above mentioned corporation to the extent of their building an intricate and costly machine, weighing forty tons, to finish the blades of the *Kaiser Wilhelm II* and the *Kronprinz Wilhelm*.

It has been the practice generally to cast the propeller blades more or less carefully to meet the specified requirements and,

without doing more than to grind off the surface imperfections, smoothing and polishing the blades, to call them a finished product. The pitch is then measured at different points and the mean of these measurements is taken and called the "mean pitch."

A brief insight into the results attained by the usual practice of making propellers will show that there are more inaccuracies than are supposed to exist.

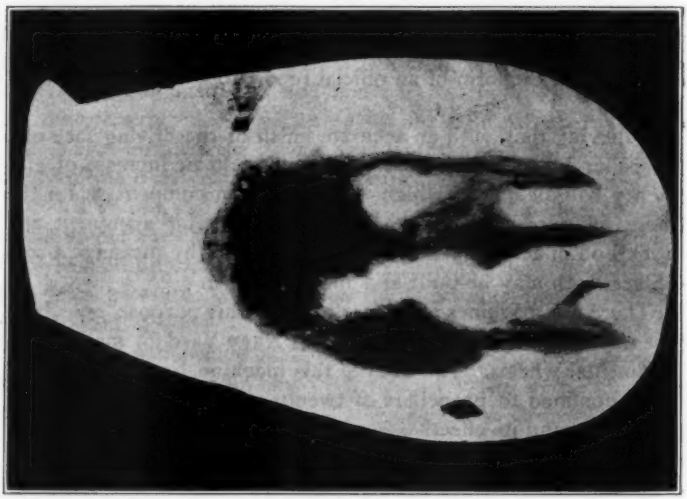
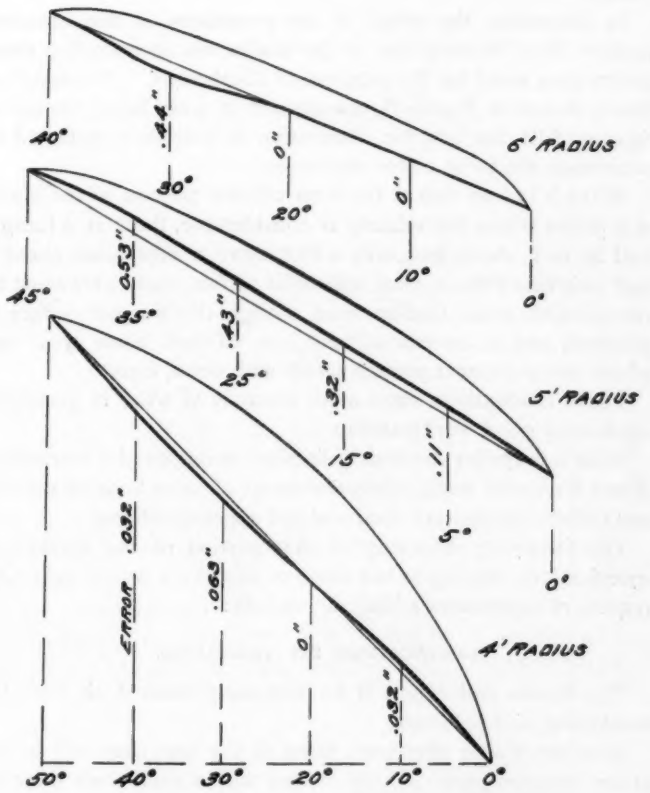


Fig. I.

Figure I is a photograph of one of the spare blades of the battleship *Missouri*. The blade was prepared, as it stood in the shop after being finished, by coating the driving face with whiting. Upon this face circular arcs were drawn at different radii from the shaft center, the planes of the circles being perpendicular to the axis of rotation. Accurate "Fair Curves" were used to show the amount of warp in the blade, and that portion of the face below the normal helicoidal surface was blackened, the deepest shade showing the greatest deviation, amounting to a difference



LIGHT LINE SHOWS TRUE HELIX
HEAVY LINE SHOWS BLADE AS FINISHED

NOTE:-
ERROR DISTORTED FOR PURPOSE OF ILLUSTRATION.

Fig. 11.

of about one-half inch from the highest "white" to the deepest "black."

In measuring the pitch of the propellers of the armored cruiser *West Virginia* one of the blades was measured at more points than usual for the purpose of illustration. The result of this is shown in Figure II, the amount of warp being shown in figures while the graphic illustration is purposely distorted to accentuate the point under discussion.

When it is seen that at the most efficient portion of the blade, at a radius where the velocity is considerable, there is a lump a half an inch above and, only a foot away, a depression about a half-inch below the normal helicoidal surface, then there must be considerably more friction, even though this warped surface is polished, and a correspondingly less efficient blade than one whose every element presses astern with equal force.

These illustrations show a fair example of what is generally considered good workmanship.

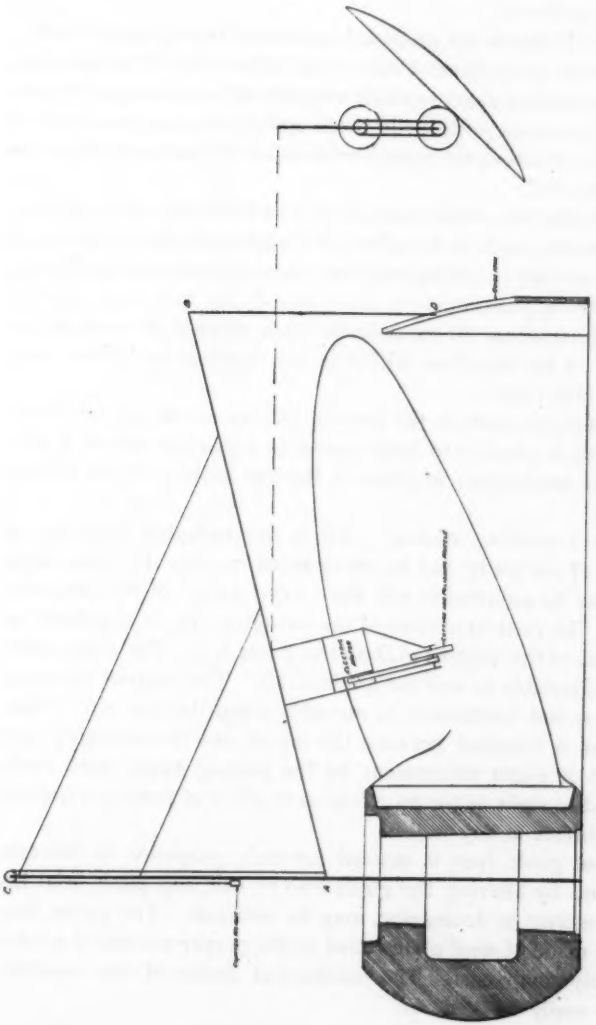
With a propeller accurately finished as designed a foundation is laid for useful study, comparisons are of value because known, and definite pitches are used and not approximations.

The following re-writing of that portion of the machinery specifications relating to the finish of propellers would definitely require of contractors a blade as desired:

SPECIFICATIONS FOR PROPELLERS.

The bosses and caps will be accurately finished all over, by machining, and polished.

After the blades have been fitted to the boss they will be set at the required pitch, and the driving face of each blade must be made a true surface as designed, by machining or other approved process, leaving the blade smooth and polished without imperfections. The backing faces must be trued as designed and finished smooth. The propellers will then be swung on a mandrel, supported and free to roll on parallel tracks, and accurately balanced by taking off the excess of metal from the backing faces of the heavier blades. The blades, bosses, caps and covers will then be tinned smooth all over. The spare blades will be treated



PROPOSED METHOD OF FINISHING PROPELLER BLADES.

Fig. 111.

in the same manner as the originals and marked for their respective positions.

Figure III shows the proposed method of fairing and finishing the blades of propellers of almost any diameter. This machine was proposed six years ago and was offered to a contracting firm building a number of torpedo boats and destroyers, but failed of recognition because the commercial value of true propellers was not appreciated.

With it the face of the pattern may be trued at a less cost than now when the work is done by hand, and every step from rough cutting to final polishing may be done without removing the blade from its position.

The illustration shows only the lines needed to explain the principle of the machine which is the application of the long used "guide iron."

The improvements in the electric motors in the last few years have made it possible to apply power to a machine where it simplifies the mechanism to allow of the free motion of the driving force.

AC is a vertical column. *AB* is the swinging arm free to move at *A* vertically, and to swing about its axis *AC*. The angle *CAB* may be adjusted to suit the "bend back" of the propeller blade. The vertical motion of the swinging arm is regulated by the travel of the support *BD* on the guide iron. The angle *ABD* is also adjustable to suit the angle *CAB*. The support carrying the motor and mechanism is movable along the line *AB*. Suitable gear is installed between the motor and the swinging arm to admit of slight adjustment by the cutting wheel both vertically and at right angles to *AB* so as to allow of cutting normally to the surface at any radius.

A new guide iron is needed for each propeller of different pitch, and by altering the guide iron to suit, any pitch, trial helix, increasing or decreasing, may be obtained. The guide iron may be made of steel plate rolled to the proper arc and at a comparatively small cost. The mechanical details of this machine may be easily worked out.

The working of the machine may be briefly described as follows:

The heavy electric motor and cutters are moved in to A, a light pointer parallel to BD is run over the blade to set it at the nearest proper angle; the high and low spots are then marked; with a pneumatic chipping tool the high spots are roughed down quickly and the finishing and polishing done by the machine.

With the number of revolutions in marine engines increasing periodically and the advent of turbine engines, propeller efficiency is of more and more moment, and I submit this report with the hope that the Bureau may see fit to incorporate in all specifications the requirements as set forth herewith.

NOTES.

REPORT OF THE COMMITTEE ON NAVAL BOILERS.

The Committee appointed by the British Admiralty to consider the subject of boilers adopted in British naval vessels has completed its investigations and has issued its report, of which the following is the full text, together with Admiral Sir Compton Domvile's letter of transmittal. This letter is of great importance in its bearing on the report now made and on the previous reports of the Committee:

H. M. S. "BULWARK", AT RAPALLO,

June 12, 1904.

Sir: I have the honor to submit herewith, to be laid before the Lords Commissioners of the Admiralty, the final report of the Boiler Committee, of which I am the president. Although I have not been present at the experiments carried out during the last two years, I have received from time to time all the reports, and they show the great care and pains taken by the Committee to obtain correct results.

2. With reference to our previous report, I am compelled to say that my experience with the Belleville boilers on the Mediterranean station has been very favorable to them as a steam generator, and it is clear to me that the earlier boilers of this description were badly constructed and badly used. We have had no serious boiler defects in any of the ships out here, and the fact that two ships are about to be recommissioned with only the ordinary annual repairs being undertaken shows that their life is not so short as I originally supposed. However, the second commission of these ships will be a very good test of the staying capabilities of their boilers.

3. In conclusion, I cannot express too highly my opinion of the work done by my colleagues on the Committee.

I have the honor to be, sir, your obedient servant,

(Signed) COMPTON DOMVILE,
Admiral and Commander-in-Chief,
President of the Boiler Committee.

THE SECRETARY TO THE ADMIRALTY.

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1. The Committee on Naval Boilers, appointed by the Lords Commissioners of the Admiralty in September, 1900, having completed their investigations and experimental trials, and being in a position to recommend standard types of boiler for use in H. M. Navy, as requested in their Lordships' letter of February 28, 1901, have the honor to submit their final report.

2. A statement of the work of the Committee up to May, 1902, was given in paragraph 2 of their report of that date. Since then the reboilering of H. M. S. *Medea* with Yarrow large-tube boilers and of H. M. S. *Medusa* with Dürr boilers, together with the necessary machinery alterations, have been completed under the supervision of the Committee, and the boilers of both ships have been thoroughly tested. The results obtained are recorded in a separate report. As requested by their Lordships in their letter S $\frac{16883}{28831}$ of November 19, 1902, the Committee have also carried out a series of trials of the Babcock and Wilcox boilers of H. M. S. *Hermes*, which extended from October 7, 1903, to May 16, 1904. These trials also form the subject of a separate report.

3. The Committee have from time to time reported the results of their investigations, and they have also answered such questions as have been put to them by their Lordships. The reports and other documents which have already been forwarded include :

(*a*) The interim report forwarded on February 19, 1901.

(*b*) Minutes of the evidence given before the Committee, together with the appendix thereto, forwarded April 26, 1901.*

(*c*) Report on the trials of the *Hyacinth*, *Minerva* and *Saxonia*.†

* The minutes of evidence have not been published.

† An interim statement by the President of the Committee was published in August, 1901.

together with a summary of conclusions, forwarded November 27, 1901.

(*d*) Progress report for the year 1901, forwarded December 31, 1901.*

(*e*) Report on the relative economy and efficiency of Belleville and cylindrical boilers in commissioned ships, forwarded April 29, 1902.*

(*f*) Report of May, 1902, with the Appendix thereto.

(*g*) Report on the trials of the *Seagull*, *Sheldrake*, *Espiègle* and *Fantôme*, forwarded August 5, 1902.

There are now submitted with this report:

(*h*) Report on the trials of the *Medea* and *Medusa*.†

(*i*) Report on the trials of the *Hermes*.†

4. The report of May, 1902, was intended to be final as regards the Belleville boiler, and the Committee have since seen no reason to modify the opinion expressed in paragraph 6 of that report, viz: that it is "undesirable to fit any more of this type in His Majesty's Navy."

5. In paragraph 5 of their report of May, 1902, the Committee stated that the experience obtained by them since the date of their report of February, 1901, had confirmed them in the opinion that "the advantages of water-tube boilers for naval purposes are so great, chiefly from a military point of view, that, provided a satisfactory type of water-tube boiler be adopted, it would be more suitable for use in His Majesty's Navy than the cylindrical type of boiler.

In their reports of 1901 and 1902 the Committee expressed the opinion that four different types of water-tube boiler, viz:

(*a*) Babcock and Wilcox,

(*b*) Niclausse,

(*c*) Dürr, and

(*d*) Yarrow large-tube,

were sufficiently promising to justify their use in His Majesty's Navy in combination with cylindrical boilers. Having concluded their experimental investigations, the Committee are now satisfied

* These reports were not published.

† These documents are not included in the report as now issued to the public.

that two of these four types, viz: the Babcock and Wilcox, similar to that tried in the *Hermes*, and the Yarrow large-tube, similar to that tried in *Medea*, are satisfactory, and are suitable for use in battleships and cruisers without cylindrical boilers. In the Babcock and Wilcox boiler the generating tubes are nearly horizontal; in the Yarrow boiler they are nearly vertical. Each type has its particular advantages, and only long experience on general service can show which is, on the whole, the better boiler. For the present the Committee unanimously recommend both types as suitable for naval requirements.

In making these recommendations the Committee recognize that the upkeep of any water-tube boiler is likely to be heavier than that of the cylindrical boiler; but they are of opinion that the two types they now recommend will cost less for upkeep than the other types of large straight-tube boiler which they have had under trial.

6. The Committee make these recommendations after investigations and trials carried out under their superintendence extending over a period of nearly four years.

The ships in which each type of boiler has been tried by the Committee are:

Cylindrical.—H. M. S. *Minerva* and R. M. S. *Saxonia.*

Belleville.—H. M. S. *Diadem* and H. M. S. *Hyacinth.*

Babcock and Wilcox.—H. M. S. *Sheldrake*, H. M. S. *Espiègle* and H. M. S. *Hermes.*

Niclausse.—H. M. S. *Seagull* and H. M. S. *Fantôme.*

Dürr.—H. M. S. *Medusa.*

Yarrow large-tube.—H. M. S. *Medea.*

7. Although the Committee have no knowledge of any type of water-tube boiler which is likely to prove more suitable for His Majesty's ships than the two recommended, there are other types which may be considered worthy of trial later on. If any type of boiler is considered, in future, to be of sufficient merit to justify its trial in the Navy, it is recommended that it be fitted in a new vessel not smaller than a second-class cruiser.

8. As in their previous reports, the Committee do not offer any remarks upon the most suitable type of boiler for small ves-

sels of high speed. From the nature of the case some form of "express" boiler, with small tubes closely pitched, is absolutely necessary, in order to obtain such a ratio of output to weight of boiler as is required in torpedo boats and destroyers. For small cruisers, however, which have to keep the sea and act with the fleet, it is probable that a boiler such as the Yarrow large-tube would, on the whole, give better results than the "express" types which have hitherto been fitted.

9. In reference to paragraph 3*b* of their Lordships' letter of September 6, 1900, and to the Committee's report of May, 1902, they desire to call attention to the breakdown of the *Hyacinth's* machinery on February 16, 1903, and to the trouble experienced with the bearings in the *Hermes* during the homeward run from Gibraltar, which strengthen the recommendation of the Committee contained in paragraph 13*a* of the report of May, 1902, viz: "They consider it desirable, where practicable, to increase the length of stroke and reduce the number of revolutions per minute as compared with the recent practice in His Majesty's service."

10. The principal comparative results on which the recommendations of the Committee are based are set forth in the succeeding paragraphs. Full details are given in the separate reports of trials.

11. *Thermal Efficiency of Boilers.*—The full tables which are appended to the Committee's reports give the efficiency of each type of boiler under very varied conditions. The results are here summarized:

The best obtained with the Babcock and Wilcox boilers of the *Hermes* were during the trials of furnace gas baffling, the boilers in the middle boiler room, with vertical baffles and a forced air supply over the fires, giving the high efficiency of 81 per cent. on a thirty-hours' trial, when 20 pounds of coal were being burnt per square foot of fire grate per hour, and an efficiency of 77.8 per cent. on a twenty-nine hours' trial when burning 27 pounds per square foot, these rates of combustion corresponding to the ordinary rate of steaming and to the full power of the boilers respectively. The boilers of the *Hermes*, with the restricted uptake baffling, and without any special air supply over the fires,

had a maximum efficiency of 75.8 per cent. on a twelve-hours' trial when burning 20.5 pounds per square foot per hour. On three trials of over twenty-four hours' duration each, and when 19 pounds were being burnt per square foot per hour, the efficiency was in each case practically 71 per cent. When burning 29 pounds per square foot per hour for seven hours, the efficiency of these boiles was 66.3 per cent.; but the weather during this test was so bad that the trial, which was to have been of eight hours' duration, had to be stopped on this account after the seventh hour. During the baffling trials, however, in good weather, an efficiency of 70.3 per cent. was obtained on the thirty-hours' trial, when burning 27 pounds per square foot per hour, or practically the full output.

The maximum efficiency of the Yarrow boilers of the *Medea*, viz: 75.7 per cent., was obtained on a twenty-six-hours' trial when burning 18 pounds per square foot per hour; their efficiency when burning at the maximum rate of combustion, viz: 40 pounds per square foot per hour for eight hours, was 69.5 per cent. On trials of over twenty-four-hours' duration each, burning from 17 pounds to 21 pounds per square foot per hour, the efficiency remained at or over 75 per cent.

The Belleville boilers of the *Hyacinth* had a maximum efficiency of 77.2 per cent. recorded on a twenty-four and one-half-hours' trial, when 16 pounds of coal were being burnt per square foot of fire grate per hour. When burning 20 pounds per square foot per hour for 11 hours, the efficiency was 73.3 per cent., and burning 17.4 pounds for twenty-four hours it was 71.8 per cent. The efficiency of these boilers on an eight-hours' trial in fine weather, when burning 27 pounds per square foot per hour, corresponding to the full output of the boiler, was 65 per cent.

The maximum efficiency of the Dürr boilers of the *Medusa* was 64.8 per cent. obtained on an eight-hours' trial, when burning 35 pounds per square foot per hour, this being the maximum rate of combustion with these boilers; the efficiency when burning 16 pounds per square foot per hour for twenty-six hours was 63.8 per cent. On trials of over twenty-four-hours' duration

each, and burning 18 pounds and 21 pounds per square foot, the efficiencies were 61.7 per cent. and 60.3 per cent. respectively.

Of the cylindrical boilers tried, those of the *Saxonia* on the only trial made, which was of thirteen hours' duration, and on which 20 pounds per square foot per hour was burnt, had the high efficiency of 82.3 per cent.

The maximum efficiency obtained with the cylindrical boilers of the *Minerva* was 69.7 per cent., which was recorded on a twenty-five-hours' trial when burning 14 pounds per square foot per hour; on a trial of eight-and-a-half-hours' duration with retarders in the plain tubes, and burning 29 pounds per square foot, the efficiency was 68.4 per cent.

In the smaller ships, the maximum efficiency of the Babcock and Wilcox boilers tried was 66 per cent. on a twelve-hours' trial, burning 18 pounds per square foot per hour in the *Sheldrake*, and 73.2 per cent. on a nine-hours' trial, burning 13 pounds per square foot in the *Espiègle*. The maximum efficiency obtained by the Niclausse boilers of the *Seagull* was 66.9 per cent. on an eight-hours' trial, burning 13 pounds per square foot, and by those of the *Fantôme* 69.8 per cent. on a nine-hours' trial, burning 14 pounds per square foot.

12. A noticeable feature in connection with the boiler efficiencies is the improvement in the results obtained with the later boilers of the Babcock and Wilcox type. The earliest of these, fitted in the *Sheldrake* in 1898, showed efficiencies ranging from 66 per cent. to 59.2 per cent.; the boilers fitted in the *Espiègle* in 1901 showed improved efficiencies, ranging from 73.2 per cent. to 63.1 per cent. Those of the *Hermes*, fitted in 1903, show a still further gain in economy, the efficiencies ranging from 75.8 per cent. to 66.3 per cent., and the same boilers, after modification, showed on one occasion the high efficiency of 81 per cent. It is noticed in this connection that the three sets of Babcock and Wilcox boilers tried differ from each other in the arrangement of their heating surface and furnace-gas baffling. The boilers of the *Sheldrake* were fitted throughout with tubes $1\frac{3}{16}$ inches in diameter, without any baffles for furnace gases; the boilers of the *Espiègle* were fitted throughout with tubes $3\frac{3}{16}$ inches in diame-

ter, vertical baffles being placed among the tubes, and causing a zigzag flow of the gases; the boilers of the *Hermes* were fitted with two rows of $3\frac{6}{16}$ inches diameter tubes, immediately over the fire, the remainder of the tubes being $1\frac{3}{16}$ inches in diameter, and the baffling of the furnace gases was effected by a restriction of the space for the passage of the gases between the top row of tubes. Those boilers of the *Hermes* which showed the efficiency of 81 per cent. were similar in construction to those last mentioned, but the baffling of the furnace gases was by a vertical system which caused a zigzag flow of the gases over the heating surface, and, in addition, a forced-air supply was introduced above the fires. (See "Report on Trials of H. M. S. *Hermes*.")

The arrangement of the heating surface in both the earlier and later boilers of the Niclausse type was the same, and the thermal efficiencies of the two sets of boilers were very similar.

13. *Wetness of Steam.*—As explained in other reports, the wetness of the steam was taken throughout the Committee's trials by means of a Carpenter's calorimeter. Experience in the *Medusa* satisfied the Committee that the results registered by this instrument are trustworthy.

As regards the production of dry steam at all rates of combustion, the Yarrow large-tube and the later Babcock and Wilcox boilers have given the best results.

14. *Loss of Water.*—The loss of feed water with each of the four types of boiler under consideration has been moderate throughout the Committee's trials. In the runs to Gibraltar and back, carried out with the *Medea* and *Medusa*, the loss of water was small, being at the rate of 1.6 and 1.8 tons per 1,000 horsepower per day respectively. On the one hundred and forty-hours' endurance trial of the *Hermes* the loss was 3.8 tons per 1,000 horsepower per day.

The loss of water may be expected to be greater in boilers fitted with many doors than in those fitted with but few, and to increase as the doors and joints become worn. In this respect the Yarrow boiler, having only three manhole doors, has an advantage.

15. *Examination and Cleaning of Interiors of Tubes.*—Of the

boilers tried by the Committee, the Yarrow boiler can be internally examined and cleaned in the shortest time and with the least amount of labor—to obtain access for such an examination and cleaning it is only necessary to remove three mahole doors. The Babcock and Wilcox type is less easily examined and cleaned—two small doors have to be removed for each tube, and these have to be rejointed after the examination and cleaning have been completed. In order to carry out a thorough examination of the tubes of the Dürr boiler it is necessary to remove a handhole door at the front of each tube, the diaphragm washer of the internal tube, the internal tube itself, and the cap nut at the back end of the generating tube; but in order to carry out a thorough cleaning, it is also necessary to remove the generator tubes from the boiler, and after the cleaning is complete these have to be replaced, this being a long and tedious process. The work connected with the examination and cleaning of the tubes of Niclausse boilers is very similar to that necessary with the Dürr boiler. Further, the cap nut at the back end of the Dürr boiler tube permits of each tube being readily emptied, while owing to the back end of Niclausse boilers being inaccessible, some process is necessary to empty the tubes when required, such as blowing the water out of the tube by a special pump and hose.

The necessity for being able to withdraw each of the tubes in a direct line with its axis renders the clear space required for the installation of Dürr and Niclausse boilers considerably more than would be required for boilers of other types. For warships, where the stokehold space is very limited, this must necessarily cause considerable inconvenience in the arrangement of pipes and auxiliary machinery.

16. *External Cleaning of Tubes.*—In both the *Medea* and the *Hermes* it is possible to partially clean the tubes externally, when the fires are alight, by means of air lances.

The tubes in the *Medea* can be thoroughly cleaned externally when the fires are not alight, as they can be swept in three directions, viz: from the furnace, from the smoke box, and from the front of the boiler. The tubes of the Dürr and Niclausse boilers cannot be so thoroughly cleaned externally in place as those

of the *Medea*, the number of rows being greater, and the overlapping of the baffles preventing portions of certain tubes being touched. In the Babcock and Wilcox boilers the tubes can be swept horizontally through side doors fitted to the casings; but as the boilers in the *Hermes* were originally fitted, the sweeping in a vertical direction was difficult. After the alterations of baffling, the sweeping vertically can be carried out, but this necessitates the removal of portions of the baffles. It is to be recognized that any system of baffling among the tubes, however it may improve the circulation of the gases, renders the cleaning of the tubes themselves more difficult.

17. *Bending of Tubes.*—After the *Medusa* had completed her preliminary runs it was found that all the tubes of the bottom rows had curved upwards in the middle, the maximum bending being $1\frac{1}{16}$ inches, and these tubes were removed and straightened before starting on the Committee's trials. These tubes had to be straightened again, in August, 1903, and again, at the conclusion of the Committee's trials, in February, 1904. When the Committee visited H. M. S. *Berwick*, in April, 1904, it was noticed that the tubes of the bottom rows of the boilers (Niclausse type) were bent upwards, and the members were informed that the maximum bending on March 22, 1904, was $\frac{5}{8}$ inch. The ship was new in 1903, and only commissioned in December of that year. With the Niclausse, and also with the Dürr boiler, considerable bending of the tubes of the bottom rows must be expected; and it will be necessary to straighten these tubes when the amount of bending exceeds $\frac{1}{4}$ inch. This will entail a considerable amount of extra work with these types of boiler, and they will be off service for corresponding periods. The upward bend of the generator tube is often greater than the space between the inner and outer tubes; and as the inner tube, which is only supported at the two ends, remains straight, it is liable to touch the outer tube at some point, thus impeding the circulation of water between them. To prevent this it may be necessary to support the inner tube at the middle of its length as well as at the back end, so that it must bend with the outer tube.

In the case of the Yarrow boilers of the *Medea* the Committee

experimented in six of the boilers with the fire rows of tubes purposely bent, as described in the report on the trials of the *Medea* and *Medusa*, with the object of overcoming some slight leakages of tube ends, which showed themselves when working under forced draft. In two boilers the tubes of the fire rows were left straight. Although these bent slightly in use, no trouble was experienced with them; and, during the later trials, these boilers proved to be as satisfactory, as regards freedom from leakage, as those in which the fire rows had been put in bent. The Committee have suggested, in their letter of December 21, 1903, concerning the Yarrow boilers proposed for H. M. S. *Warrior*, that the tubes of the fire rows should be bent 1 inch from the straight, and this recommendation they think should apply to future designs.

In the Babcock and Wilcox boilers of the *Hermes*, although some of the tubes of the bottom rows have bent, no leakage of tube ends has resulted, and it has not been necessary to remove any tubes for straightening or renewal.

18. *Corrosion of Tubes and Wear of Casings and Up-Takes.*—In none of the four types of water-tube boiler which were recommended for trial by the Committee has there been any considerable corrosive decay of tubes, and the ordinary wear has been very slight. On the conclusion of the Committee's trials the tubes of the boilers of the *Medea* and *Hermes* had not deteriorated to any appreciable extent. This applies also to the *Medusa*, except that the internal tubes have shown signs of roughening.

In the *Medusa* (Dürr boilers) there was some buckling of the side casings of the boilers, and some of the casing doors at the back of the boilers became warped and burnt.

No trouble was experienced in connection with the casings and uptakes of the Yarrow boilers of the *Medea*, and very little with those of the Babcock and Wilcox boilers of the *Hermes*. From the experience of the Committee with the boilers of the S. S. *Martello*, employed on the Atlantic trade for nearly four years, and also from their experience to date with the *Hermes*, it is considered that the durability of the casings and uptakes of

Babcock and Wilcox boilers will prove to be satisfactory under the ordinary conditions of naval service.

In the Yarrow boiler the temperature of the furnace gases is considerably reduced before they reach any part of the side casings; and, in consequence of this moderate temperature, the casings and uptakes of the *Medea's* boilers were uninjured on the conclusion of the Committee's trials.

In this respect the Yarrow boiler is superior to the other types of water-tube boiler which have been tried by the Committee.

19. *Liability to Damage from Being Forced.*—The makers of the Dürr boilers stated that not more than 35 pounds of coal should be burnt per square foot of fire-grate per hour in the *Medusa.* The Committee consider that this limitation of the quantity of coal to be burnt was prudent, as the overheating and bending of tubes in one of the boilers during the full-power homeward run from Gibraltar were, in the opinion of the Committee, due to the fact that the safe limit had been exceeded. It is also considered that the limitation of the amount of coal to be burnt per square foot of grate applies with even greater force to the Niclausse boiler, as the supply of water to the tubes is freer in the case of the Dürr boiler than in that of the Niclausse. As a result of their trials the Committee find that the Yarrow boiler can be severely forced without danger, and that the Babcock and Wilcox boiler can with safety be forced to the extent shown in the reports.

20. *Skilled Firing Required.*—The satisfactory stoking of water-tube boilers requires a higher degree of skill than that of cylindrical boilers, and this is more necessary with the large grates of the Dürr, Niclausse and Babcock and Wilcox boilers than with the smaller grates and better shape of combustion chamber of the Yarrow. The stoking in the *Medea*, *Medusa* and *Hermes* was good throughout the trials, and towards the end was excellent. Under ordinary service conditions such good firing can hardly be expected, at least until a vessel has been some time in commission. Good results can, however, be obtained with Yarrow boilers with engine-room complements new to the ship, as shown

by the trials to Malta and back which have been made by the *Medea* since the completion of the Committee's trials with that vessel.

21. *Superheated Steam.*—The Dürr boiler was the only one tried by the Committee which had any arrangements for superheating. It was fitted with complicated directing plates in the steam collector and with superheater tubes. The fittings in the steam collector are undesirable, and they and the superheater tubes will probably require frequent renewal, while the amount of superheat obtained by their use was small, even when the temperature of the funnel gases was abnormally great. The results obtained were not sufficient to enable the Committee to express any opinion as to the value of superheating as applied to naval boilers.

22. *Feeding of the Boilers.*—No trouble has been experienced with the feeding of any of the four types of boilers under consideration. In the *Medea* and *Medusa* the boilers were fitted with automatic feed regulators. It was found, however, that these were not sufficiently sensitive in opening and closing (allowing a variation of level of about 6 inches in the gauge glass); the feed was, therefore, regulated throughout the trials by hand, no trouble being experienced in doing this. For a similar reason the feed was regulated by hand in the *Hermes* during the trials. In the *Medea* the feed regulators were inside the steam collectors, and interfered with the examination and cleaning of the middle rows of tubes. The Committee consider that the balance of advantages rests with the omission of automatic feed regulators in boilers—such as the Yarrow large-tube and the Babcock and Wilcox, where there is a fairly large reserve of water in the boiler.

23. *Salt Water.*—The report on the trials of the *Medea* and *Medusa* contains a description of experiments made on the Yarrow and Dürr boilers in regard to their behavior when working with brackish water. These experiments, so far as they went, indicated that neither type of boiler was likely to give trouble from this cause. In the case of the Yarrow boiler this result has been corroborated by the fact that on a recent voyage the

Medea is reported to have had leaky condenser tubes, and a corresponding density in the boilers, without any bad effect.

24. *Relative Weights.*—In the case of the *Hermes*, the *Medea* and the *Medusa*, the new boilers were installed without any alterations being made in the stokehold floor spaces. A comparison of weight and maximum output of the boilers gave results tabulated below.

25. The Committee are under great obligations to Mr. C. J. Wilson, F. C. S., who has, during the four years of their work, given his valuable personal attention to the analyses of funnel gases and of coal samples without any remuneration. They are also much indebted to Messrs. Thomas Wilson, Sons and Company, for permission to examine the boilers of the S. S. *Martello*, and to Mr. W. S. Hide, the superintending engineer of that company, for affording the Committee facilities for carrying out the inspections and giving information concerning the results obtained in the running of that vessel.

WEIGHTS AND MAXIMUM OUTPUT OF VARIOUS TYPES OF BOILERS.

Type of boiler.	Ship.	Weight of boiler-room installation.	Maximum output of steam per hour.	Output of steam per hour per ton of boiler-room weights.	
		tons.	*pounds.*	*pounds*	
Cylindrical	*Saxonia*	1,000 (about)	132,600	132.6	
do	*Minerva*	567	167,100	295	With retarders.
do	do	558	156,200	280	As originally fitted.
Belleville	*Hyacinth*	454	178,700	394	
Yarrow	*Medea*	330	157,800	478	
Dürr	*Medusa*	314	158,000	503	
Babcock and Wilcox	*Hermes*	490	200,000	410	With vertical baffles and forced-air supply above the fires.
do	do	481	182,300	380	As originally fitted.
do	*Sheldrake*	125	43,840	351	
do	*Espiègle*	95	24,780	261	
Niclausse	*Seagull*	135	48,450	359	
do	*Fantôme*	76.5	22,750	297	

26. The Committee desire, in conclusion, to place on record their appreciation of the assistance which they have received

from their Secretaries. Captain Browning, R. N., acted as joint Secretary until his appointment to H. M. S. *Ariadne*, in 1902. Engineer-Lieutenant W. H. Wood, R. N., has continued to act as Secretary throughout their whole work. The diligence and energy which the latter officer has shown in carrying out his work, his knowledge of the scientific, as well as of the practical, side of marine engineering, and his capacity for dealing both with details and with general organization, have been invaluable to the Committee throughout, and especially in connection with the carrying out of their boiler trials at sea, a work of no little difficulty and complexity; and they desire to bring his services to the favorable notice of their lordships.

(Signed) COMPTON DOMVILE,
(*Admiral and Chairman*),
JAS. BAIN,
JOHN INGLIS,
ALEX. B. W. KENNEDY,
JOHN LIST,
J. T. MILTON,
JOS. A. SMITH.

WM. H. WOOD, *Secretary*.

THE BOILER COMMITTEE'S REPORT.

Comment by "Engineering," London.

We have dealt with the interim reports of the Committee from time to time as they have been issued, and there is, it will be seen, in this last report a list of the matter already forwarded to the Admiralty by the Committee. The facts and opinions contained in these documents comprise one of the most valuable collections of data ever put together on an engineering subject. The engineering ability and reputation of the members of the Committee, and their independent position, as being mostly unconnected with the Admiralty—nor concerned with the production of boilers—render the reports additionally valuable. The thanks of the country at large, and of engineers all over the world, are due to those who have given their time so lavishly,

and have undergone many privations and discomforts in the course of an inquiry which has extended over a period of nearly four years.

The report we now publish is, in some respects, more valuable than those which preceded it, inasmuch as the conclusions reached are very definitely set forth. Briefly it may be said, the Belleville boiler, for the trial of which the Committee was really constituted, is condemned, and two other types of water-tube boiler are preferred in its stead. We have on former occasions dealt very fully with the merits and demerits of the Belleville boiler; but as this will probably be our last word on the subject, in connection with this long inquiry, we will briefly recapitulate our main conclusion. Broadly, the opinion we have expressed has been that the Belleville boiler was, for warships, preferable on the whole to the old pattern of Navy boiler of the return-tube type which it succeeded, and for a time it was the only boiler of the water-tube description of which there was any extended sea-going experience. Later, other types of water-tube boiler were found to be superior to it for large as well as for smaller vessels of war. How far these views have received confirmation our readers can judge from the present report. We would especially call attention to Admiral Domvile's covering letter, which has reached us since the above was written. His testimony as to the favorable performance of the Belleville boiler is especially valuable as the result of actual sea-going experience. We would like to add that the Belleville boiler has often not been given a fair chance. We do not mean to say there has been enmity against it; indeed, every effort appears to have been made by the engineering authorities of the Admiralty and the Royal Navy to make it a success; but the engineering department has not sufficient power to put its views into practical shape. This has been in the past, but is still, to some extent, a serious defect in our naval administration—that engineering opinion is overridden by those who have no knowledge of engineering subjects. Engineers are subject to the control of the Board of Admiralty—which includes no engineering element—and is, in turn, largely dominated by political considerations. This element in

our naval policy has operated to the disadvantage of the Belleville boiler.

So much may be said in justice to the Belleville firm, who deserve our admiration as having been the pioneers in the practical introduction of water-tube boilers afloat. For very many years before we ventured to try a Belleville boiler in warships the late M. Belleville advocated the use of water-tube boilers; and though this type of steam generator was introduced many years previously to his era, it was he who brought to France the credit of being the first country to install, on a large scale, that type of boiler which has practically become universal in the navies of the world. There is no need to say more on this aspect of the question. We respect the late M. Belleville and those who have succeeded him for what they have done, but we must recognize that others have now gone beyond them. The Boiler Committee prefer other water-tube boilers to the Belleville type, and we agree with their conclusions.

It will be remembered that in the previous reports of the Boiler Committee water-tube boilers of four types were selected as sufficiently promising for further use in combination with cylindrical boilers. These were the Babcock and Wilcox, the Niclausse, the Dürr and the Yarrow large-tube boilers. Further investigation, it will be seen by the present report, has resulted in the list being practically narrowed to the Babcock and Wilcox and the Yarrow boilers, for these two are pronounced "satisfactory and suitable for use in battleships and cruisers without cylindrical boilers." Both these types of boiler are well known to our readers. They differ in fundamental principle, in the Yarrow boiler having tubes approximately vertical, whilst the tubes in the Babcock and Wilcox boiler are slightly inclined from the horizontal; the tubes in the former are, moreover, considerably smaller in diameter than some of those of the latter. The bearing of this point will be dwelt upon later. It will be remembered in connection with this part of the question that the Committee only deal with the problem of boilers for large ocean-going vessels, leaving the question of "express" boilers for small quick-steam craft out of their inquiry.

The report states that the Yarrow and the Babcock and Wilcox boiler have each its particular advantages, and that which is the better boiler can only be determined by long experience on general service. Certain details are, however, given, and by means of them engineers may, perhaps, be able to form more definite opinions of their own. In the first place, the Committee recognize that the upkeep of any water-tube boiler is likely to be heavier than that of the cylindrical boiler. That may be the case at the present time; but it is possible that when further experience has been gained the cost of upkeep may be very materially reduced, both in regard to making the boilers more durable—weak features being discovered and eliminated—and by improved and cheaper methods of effecting repairs. The cylindrical boiler has a very long start in this respect. As matters stand, we think it probable that some of the members of the Committee may have been influenced by their experience with boilers of the mercantile marine, and have used this as a standard of comparison. If we were to compare the cost of upkeep of the present water-tube boiler of the best type with that of the Navy return-tube boilers—which it superseded—we doubt whether the debit balance would be always against the water-tube type. It is true that the desire to save weight had at one time led to cylindrical Navy boilers having their tubes crowded together and reduced in diameter to a dangerous extent, thus increasing the chance of breakdown and adding to the cost of repairs; but it is necessary to consider the whole question, and if we take the comparatively modern cylindrical boilers of the *Minerva* and compare them with those of the Cunard liner *Saxonia* we find that, weight for weight, the former generated more than twice as much steam as the latter.

The figures on this subject of boiler-room weights brought together in the reports are very suggestive. The *Saxonia's* boilers generated only 132.6 pounds of steam per hour for each ton of boiler-room weight, whilst the cylindrical boilers of H. M. S. *Minerva* produced 295 pounds of steam with the same boiler-room weight. It is, however, when we come to the water-tube boilers that we see the great saving in weight that can be effected. The Dürr boiler heads the list with 503 pounds of steam per ton.

The Yarrow boilers stand next with 478 pounds of water evaporated per ton of boiler-room weight. The Babcock and Wilcox boiler has, at its best, 410 pounds per ton. This result was obtained in the *Hermes* when vertical baffles were fitted to direct the hot gases more advantageously over the heating surface, and there was a forced-air supply above the fires. As the boilers in this ship were originally arranged, the evaporation was 380 pounds per ton of boiler-room weight. The inconvenience of baffles must not be forgotten.

Under the more favorable conditions stated, the efficiency of the *Hermes* boilers was 81 per cent. on a thirty-hours' trial, when 20 pounds of coal were being burnt per square foot of grate per hour. This is almost as high as the remarkable figure of 82.3 per cent. obtained with the *Saxonia's* boilers on a thirteen-hours' trial, and burning the same proportionate amount of coal. It is to be regretted that the Committee were not able to secure a trial on a type of ship more nearly approaching a modern cruiser in regard to speed, such as one of the fast Atlantic liners. The *Saxonia* is, of course, an admirable example of her class; but in these slower cargo-carrying liners, coal economy, leading to higher boiler weights, is a leading feature. Had a higher speed been aimed at in the design of the vessel the fuel efficiency of the boilers would, doubtless, have been somewhat less; and the boiler-room weight would have compared more nearly with that of war vessels. On the higher power trials of the *Hermes* the Babcock and Wilcox boiler came out very well. When burning 27 pounds of coal per square foot of grate, the efficiency was 77.8 per cent.

With the Yarrow boilers in the *Medea* the maximum efficiency was 75.7 per cent. This was obtained on a twenty-six hours' trial when burning 18 pounds of coal per square foot of grate per hour. As almost as good a result was obtained when 21 pounds of fuel were burnt, the figure may be compared with the trials of other vessels burning 20 pounds of coal. At the maximum rate of combustion, when the high ratio of 40 pounds of coal per square foot of grate per hour was reached, the Yarrow boilers gave the satisfactory figure of 69.5 per cent. It is a great

advantage of the Yarrow boiler that the efficiency falls but slowly as the duty is increased; in other words, it has a high range of efficiency. This quality of being forced to a high degree without marked loss or damage is of great tactical importance. In war such a safe reserve of power in the hands of a commander would be apparent. In peace also it is a great comfort to the engineer. When ships are steaming in squadrons, and have to keep formation, the commanding officer will often call for sudden increase of speed, and to obtain this more steam is naturally required. The maintenance of fuel economy when the boilers are forced is not only a strategical but also a tactical question, for it is well known that to bring the fuel to the boilers is one of the most difficult operations when full speed is needed; and, naturally, the less coal required the less the difficulty.

The efficiencies of the other boilers tried will be gathered from the report, and do not call for comment here, as our chief interest is centered in the two types which are the final selection of the Committee. It should be noticed, however, that in the smaller vessel (the *Sheldrake*) tried, the maximum efficiency of the Babcock and Wilcox boiler was 66 per cent. on a twelve-hours' trial when burning 18 pounds per square foot of grate per hour—a fact which indicates the improvements since made in the design of this boiler. The boilers of the *Sheldrake* were fitted with tubes $1\frac{3}{16}$ inches in diameter, and there were no baffles for furnace gases; the boilers of the *Espiègle*, with baffles among the tubes, showed a better result; whilst the *Hermes*, fitted in 1903, gave the still higher efficiency named. The boilers of the latter vessel had two rows of tubes $3\frac{5}{16}$ inches in diameter immediately over the fire, the remainder of the tubes being $1\frac{3}{16}$ inches in diameter (as in the *Sheldrake*), whilst the baffling of the furnace gases was effected by narrowing the spaces between the top row of tubes. It should be noticed, however, that the highest efficiency of the Babcock and Wilcox boiler was obtained with examples in which a vertical system was fitted, so as to cause a zigzag flow of gases. This is an important detail, as baffles amongst tubes are an obstruction to cleansing operations; and the report contains some suggestive remarks on this point. It

states that in the Babcock and Wilcox boilers the tubes can be swept horizontally through side doors fitted to the casings; but as the boilers in the *Hermes* were originally fitted, the sweeping in a vertical direction was difficult. After the alterations of baffling were effected, vertical sweeping could be carried out by removal of some of the baffles. "It is recognized," the report adds, "that any system of baffling among the tubes, however it may improve the circulation of the gases, renders the cleaning of the tubes themselves more difficult." When the fires are alight, it is possible to partially clean the tubes of the Babcock and Wilcox boilers in the *Hermes* by means of the air-lance. The tubes of the Yarrow boiler can be cleaned in like manner; but when the fires are not alight, the Yarrow tubes can be thoroughly cleaned externally, as it is possible to sweep them in three directions—namely, from the furnace, the smoke box, and from the front of the boiler.

The above figures refer to the cleaning of the exterior of tubes, but the report also gives some information on the cleansing of the interior of the tubes. "Of the boilers tried by the Committee," we are told, "the Yarrow boiler can be internally examined and cleaned in the shortest time and with the least amount of labor;" it only being necessary to remove three manhole doors. "The Babcock and Wilcox type is less easily examined and cleaned, for two small doors had to be removed for every tube, and these had to be rejointed after the examination and cleaning had been completed."

A detail of considerable interest in conection with water-tube boiler design is the bending of tubes due to expansion by heat. It has been held that the free-ended tube type of boiler, such as the Niclausse and the Dürr, would not suffer through expansion and contraction, because the tubes would be free to become longer and shorter with variations of temperature, and consequently there would be no unusual stresses thrown on the metal of the tube or on the joints. Moreover, as the tubes were not held between tube plates each one could expand freely longitudinally, and therefore they would not bend. That is a theory that was advanced, but the report tells us that after the *Medusa*,

fitted with Dürr boilers, had completed her preliminary run, "all the tubes in the bottom row had curved upwards in the middle;" the maximum bending being $1\frac{1}{16}$ inches. These tubes were straightened before starting on the Committee's trials, again in August, 1903, and once more in February, 1904.

Another case of bent tubes mentioned in the report was that of H. M. S. *Berwick*, a vessel fitted with Niclausse boilers. The Committee visited this ship last April and found that the bottom rows of tubes were bent upwards; they were informed that the maximum bending in March of this year was $\frac{5}{8}$ inch. The ship was first commissioned in the preceding December. On the other hand, in the Babcock and Wilcox boilers of the *Hermes* some of the bottom tubes—which, of course, are fixed at each end—have bent, though no leakage of the tube ends resulted, and it was not necessary to remove them for straightening or renewal.

These facts have considerable bearing on the design of water-tube boilers in regard to the important detail of diameter of tubes, especially those subjected to the radiant heat of the furnace. The difference in temperature between the upper and lower sides of the tube causes unequal expansion results. The tubes in the *Medea's* boilers were all $1\frac{3}{4}$ inches in diameter. In boilers of the type of the Yarrow or the Babcock and Wilcox, on the other hand, in which the tubes are held at each end by drums or headers, the conditions are different to those present in boilers with tubes having free ends, such as the Niclausse and Dürr types. In the Yarrow or the Babcock and Wilcox boilers bending may be caused by one tube becoming hotter than its neighbors, and thus having a greater tendency to expand. If this expansion reaches an extent beyond that which can be taken up by compression of the metal, it can only be provided for by the bending of the tube between the tube plates; supposing, of course, the joint did not give way. It should be remembered, however, that a considerable tendency of the tube to expand may be taken up by the compression of the metal without it being stressed beyond its elastic limit. The tubes in the *Hermes'* boilers, except the bottom rows, were, as stated, $1\frac{3}{16}$ inches in

diameter, and, therefore, seeing they were held at each end, one might (on the old assumption, seeing they were the weaker column) have expected them to bend before the larger 4-inch tubes; but we gather from the report it was only the latter that gave way. The tubes in two of the Yarrow boilers of the *Medea* "bent slightly in use," but no trouble was experienced with them; whilst in six of the boilers the tubes of the fire rows were purposely bent. In neither case was there trouble from leakage.

The conclusion to be drawn from these facts is that fixed tubes also may have an inherent source of weakness. Whether the stresses set up will lead to strain sufficient to cause the tube joints to leak after a more or less considerable period of use is a problem that will be solved by experience; but it should be noted that whatever weakness may exist owing to this cause will be more likely to become apparent under the stress of war, when the boilers are called upon for their highest duty. It may be added that circulation has also an influence on tube bending, and here the difference between vertical and horizontal tubes may be of importance. Naturally, where the circulation of water is vigorous, and bubbles of steam are swept away as soon as formed, the temperature of the tube is more likely to be uniform all round than in cases where the circulation is sluggish.

In the Niclausse and the Dürr boilers bending of tubes is more serious, because, as the report points out, when the curvature reaches a certain degree, the inner circulating tube will touch the outer one, thus impeding the circulation of water between the two. To prevent this it may be necessary to support the inner tube at the middle of its length, so that it will have to bend with the outer tube. As illustrating these remarks, it may be added that there is no surer way of bending tubes than by introducing oil into the boiler.

The remaining features referred to in the report speak for themselves. The facts recorded in regard to corrosion of tubes and wear of casings and uptakes appear generally satisfactory, especially in the case of the Yarrow boiler; the latter also appears to advantage when forced, the report stating that "the Yarrow boiler can be severely forced without danger;" a circum-

stance that would be gathered from theoretical considerations, and, moreover, is borne out by the severe experience of trials with destroyers and torpedo boats. It is also stated that "the Babcock and Wilcox boiler can with safety be forced to the extent shown in the reports." Skilled firing, we know, is needed to get the most economical results with water-tube boilers, but that, we consider, is not altogether a defect for warship practice. The need for higher intelligence and adequate training is the distinguishing feature of the modern navy. It is no advantage, but rather a danger, for a considerable part of the *personnel* to consist of crude and uninstructed men. If a stoker cannot fire a water-tube boiler—and there is no special magic about it—he should have no place on board a man-of-war. Our constant effort should be to raise the status in every department, and necessity tends to this end. The report states, however, that "good results can be obtained from Yarrow boilers with engine-room complements new to the ship." That may be true of these boilers, but they should never be put to the test, if we translate "new to the ship" as "new to that kind of ship."

It is to be regretted the Committee did not secure data sufficient to enable them to express an opinion on the important question of using superheated steam. In another detail, from which it was originally thought difficulty would arise, satisfactory results were obtained, as the Committee experienced no trouble in feeding any of the four types of boiler under consideration. It was found, however, that hand regulation was superior to automatic devices, and in Yarrow and Babcock and Wilcox boilers experience showed there was a fairly large reserve of water. The experiments made with the Yarrow and Dürr boilers indicated that they might be safely fed with brackish water. In the case of the Yarrow boiler, the voyage of the *Medea* from Malta corroborates this view, as the condensers leaked, and a certain density in the feed water did not have a bad effect. Our readers well remember some severe experiments carried out a few years ago on a torpedo boat fitted with a Yarrow boiler, the results of which showed that sea water could be used as feed for a considerable period without appreciable defect.

In conclusion, we would again draw attention to the valuable nature of the report, and congratulate the members of the Committee upon having brought their long task to a conclusion. It is satisfactory to know that in this important branch of steam engineering the technical skill and inventive ingenuity of an English firm has placed this country in the foremost position. It may also be pointed out that though the Babcock and Wilcox boiler is of American origin, it has for some time been acclimatized in this country, and many of the improvements which have rendered it a success for marine purposes have resulted from British experience.

MILITARY AND STRATEGICAL VALUE OF OIL FUEL.

It is for very weighty reasons that the United States Navy has been engaged in a most searching investigation of the question of oil fuel for the Navy. Although it is true that the whole industrial world will be benefited by the voluminous data of the most reliable character that will be available, it was, primarily, to learn the exact value to the Navy as regards the efficiency of its ships, both individually, considered as fighting units, and collectively, in respect of their strategical efficiency in relation to the fleets and fortifications of friend and foe, that this investigation was begun some two years ago.

The superior advantages of oil fuel over coal as affecting the design of warships and their subsequent handling are well known. In the first place, oil, because of its superior heating qualities, weighs less and occupies less bulk, compared on a basis of total thermal value, than coal. Therefore, the difference in weight and bulk in a ship designed to use oil fuel represents so much weight that may be worked into that ship to improve her qualities, either by building her stronger in the hull, or by making a proportionate increase in the weight of her armor or in the number of her guns, or by providing her with a larger fuel supply.

Oil fuel has, moreover, the valuable quality that it can be stowed in the watertight compartments of the double bottom of the ship, thereby permitting the very considerable space which is taken up by coal bunkers to be utilized by the naval constructor

for other purposes, if he so desires. The effect of the substitution of oil fuel on the *personnel* of the ship would be to make a great reduction in the fireroom staff, the crowd of stokers being replaced by a few men with some slight engineering knowledge, who would be easily able to look after all the necessary pipe connections and burners for carrying the oil to the boilers and properly burning it in the furnaces. Furthermore, much of the delay, and all of the dirt and inconveniences, which make the work of coaling a ship the *bête noir* of the naval man, would be removed; since the oil could be piped by gravity from the tanks of the fuel supply station, or pumped from the fuel supply ship, directly into the tanks of the warship. Finally, there is the welcome riddance of ashes, with their necessary installment of ash hoists and chutes, to say nothing of the labor involved in their removal.

The question of the extensive use of oil fuel in the Navy has a special strategical importance for the United States, and this for the reason that we are next to the largest, if not the largest, producers of oil fuel in the world. Comparing our position with regard to this question with that of other great naval powers, it may truly be said the oil-fuel question is paramount, no other leading naval power being able to tap its supply of oil directly from so many widely-scattered centers. Thus the great oil fields of Louisiana and Texas lie within pipe-line distance of the Gulf of Mexico, the value of the naval control of which by the United States is universally admitted, particularly with reference to its relation to the Panama Canal. The oil fields of Pennsylvania are connected by pipe line with the three great ports of Baltimore, Philadelphia and New York, thereby serving the ships of the North Atlantic station at three different points; while on the Pacific coast the port of San Francisco is similarly connected with the oil fields of California; and, from this last source, it would be possible to keep supplied the storage tanks of fuel stations at three widely distributed points, namely, the Hawaiian Islands, the Philippines, and the Aleutian Islands. Of course, it must be recognized that the storage of fuel at various stations answering to coaling stations would require special provisions as compared with the storage of coal, since the oil must neces-

sarily be placed beyond the reach of shell-fire from a hostile fleet. To this, however, oil fuel would lend itself admirably, since the tanks could be placed inland, beyond the range of hostile fire, and the oil piped from these tanks to the docks. A further valuable advantage of the use of oil would be that the most important problem of coaling at sea would be simplified; since it would be sufficient to connect the tanks of the fuel supply ship by flexible hose with the fuel tanks of the warship and pipe the oil from one to the other while the supply ship was in tow.—"Scientific American."

RAPID COALING OF WARSHIPS IN PORT.

The British Admiralty are endeavoring to expedite the coaling of warships while in port. It is imperative in case of hostilities, when a warship has to return to its naval base for fresh fuel supply, that such replenishment should be carried out as rapidly as possible, in order to permit the vessel to return to the scene of operations, or proceed on its journey. For this purpose the Navy Department is acquiring special floating coal depots of different types and dimensions, adaptable to various ranges of operations.

The latest type of this floating coal reservoir has been delivered to the dockyard at Portsmouth. It has been constructed by Swan, Hunter & Co., of Wallsend-on-Tyne, and is of huge dimensions. The depot is constructed for carrying 12,000 tons of coal, and is sufficiently large to enable two first-class battleships or four smaller vessels to be berthed alongside and coaled simultaneously. The actual coaling operation is accomplished by means of Temperley transporters, three of which are erected upon each of four platforms with which the depot is provided. The depot will be moored at a suitable place in the harbor. Its advantage over projecting piers is that it can be towed to any desired position whenever required. With this type of coaling reservoir the fuel will be transported to the bunkers of the war vessels with much greater celerity and ease than is at present possible.

Another type of coaling device which has proved highly successful is what is known as the "haulabout." These haulabouts are plain steel hulls, similar to barges, with hatchways extend-

ing nearly across the vessel. Fitted to each haulabout are two self-contained Temperley traveling tower transporters, the beams of which have a very long overreach on either side, and are sufficiently high to take coal from a large collier, and deliver it directly to the boat deck of the largest battleships or cruisers, if necessary. For the purposes of transshipping the coal from the colliers to the hold of the haulabout, the towers are made to travel the full length of the vessel. Thus they command the full extent of the hull of the barge both in filling and discharging. The capacity of a haulabout is 1,000 tons of coal.

Each tower of the transporter is fitted with a steam boiler and special engine for hoisting and conveying the load, for raising and lowering the overhanging parts of the beam and for propelling the tower along the rails. This engine is also fitted with gearing and lifting tackle for removing and replacing the hatch covers, which are picked up and carried to the end of the vessel by traveling the towers along in the usual way.

These haulabouts have been specially designed to provide a coaling vessel of considerable storage capacity, capable of being hauled about from vessel to vessel, where it can either supply coal from its own hold or be used for discharging coal direct from the collier to the vessel to be coaled. The vessels are capable of filling their own holds, either from colliers or from the shore, for which purpose they are supplied with automatic dumping buckets.—"Scientific American."

STEAM TURBINE LITERATURE.

The following is quoted from an editorial in "Engineering News" upon the four papers on steam turbines read at the international meeting of the English and American Societies of Mechanical Engineers at Chicago:

"We print these papers, however, with full recognition of their limitations and defects; they are valuable because better and more complete literature on the subject is not to be had; and because it behooves the engineer of the present day to post

himself on the steam turbine question by the best means available.

"So far as quantity is concerned, there has been no lack of literature on steam turbines. The several concerns engaged in the commercial exploitation of steam turbines have waxed diligent in contributing papers on their machines to the pages of technical journals and the proceedings of technical societies, but they have been, quite naturally, careful to give out for publication only the roseate side of the story. Accordingly, the engineering profession has been thoroughly informed as to the advantages of the steam turbine. We all know how compact it is, what high results in steam economy it can show under test, how little this economy falls off under variable load, how it saves in the cost of dynamo construction, how little oil it requires, how the steam can be discharged into a surface condenser and used over and over again with resultant saving in feed-water expense.

"All these claims have been diligently spread before the public; but one may search long and find little concerning the other side of the story; and what the prospective user of steam turbines or the engineer who advises him wishes to know is not the strong points of the turbine, but the weak points. Before one takes the step of purchasing a machine which is such a radical innovation on past practices as the steam turbine, he wants to know what difficulties he is going to encounter. To read an article extolling the turbine as a marvel of perfection and preserving an entire silence as to its defects is apt to set a conservative engineer at work investigating to find what these defects may be.

"Now, there is nothing like a little healthy competition to spead knowledge concerning the defects and weak points of any class of products, and the prospects are excellent at present for a season of sharp competition in the steam turbine business.

"Thus it happens that in the four papers read at Chicago last week by the representatives of four different turbine makers, the several contributors managed to reveal some of the defects of their competitive machines, and incidentally of steam turbines in general.

"In making our abstracts and condensations of these several papers, we have been careful to preserve those portions intact in which each author criticised his competitor's designs; and the whole symposium is calculated, we believe, to be of much practical usefulness to the engineer responsible for the selection or purchase of a steam turbine. It is true, of course, that very much more knowledge than is given in these papers would be desirable; but enough is given to put the engineer on the search for more.

"Thus we learn that, notwithstanding the published claims that the turbine buckets run for years without erosion, it appears that under some circumstances quite rapid erosion does occur. We learn that a minute variation in adjustment of the working parts, such as wear is likely to cause, may affect very considerably the steam economy of a turbine. We learn that centrifugal force sets up heavy stresses in the rotating parts of turbines, and that in case any accident causes it to run above its rated speed these stresses may become great enough to burst the rotating part.

"It appears, furthermore, that a turbine is pretty closely dependent on the condenser for high efficiency and demands a high vacuum for the best results. A year or more ago a factory in New England was equipped with a steam turbine, supposed to be of ample power for the work, but the power was based on condensing practice with a good vacuum. The condenser as installed proved inadequate to maintain the vacuum, and as a result the turbine could not deliver its rated power, and part of the factory had to be shut down till additional power could be obtained.

"These are some of the things which engineers, we believe, want to know about steam turbines, and the steam turbine manufacturers might as well tell them. In the long run, they will make more customers, and their customers will be better satisfied, if they let them know in advance just what difficulties they are likely to meet, or, in other words, just what they must pay to offset the admitted advantages of the steam turbine.

"It is altogether probable, moreover, that the makers of steam turbines have themselves much to learn and that in the

rapid evolution that is now going on, the steam turbine of ten years hence will be a very different machine from that of to-day. It is comparatively easy to build a machine which will effect a certain end; but it requires slow evolution through large experience to adapt that machine to all the conditions of use, to facilitate construction, erection, cleaning, lubrication, maintenance, renewal of parts, inspection, attendance, etc.

"One other fact which deserves notice here is that the advantageous applications of the steam turbine, apart from dynamo driving, are yet to be demonstrated. There is much popular enthusiasm concerning its application to the propulsion of vessels, but, as Professor Rateau points out, its use in this field, aside from vessels intended for phenomenally high speed, is of doubtful advantage. Propellers to run at the high rotative speed of a steam turbine are bound to be inefficient, and while the turbine itself is a perfectly balanced machine, the propeller is likely to set up worse vibrations in the hull than those caused by reciprocating engines.

"Probably the most promising field for the use of steam turbines, aside from the electrical field, is the driving of centrifugal pumps. There is good reason to believe that the turbine-driven centrifugal pump may actually displace the reciprocating pump in many fields. It is such a small and inexpensive machine to build compared with the slow-moving steam pump, and the advantage is so great in dispensing with a multitude of valves and packings and stuffing boxes, that the manufacturer who will place a satisfactory unit of this sort on the market should find plenty of patronage. Of course, here again erosion is likely to be a matter requiring attention; but the castings for the pump once made could probably be renewed at a small expense compared with the cost of keeping up the valves and packing and all the other multitudinous parts requiring attention on the ordinary direct-acting steam pump."

APPARATUS FOR INCREASING VACUUM IN CONDENSERS.

An arrangement of vacuum intensifier has been designed by the Hon. Charles A. Parsons, Newcastle-on-Tyne, for improving

the vacuum in a surface or jet condenser. The device consists in a combination of an air pump with a propelling jet operated by steam, whereby the gases and vapors proceeding to the air pump are assisted in their progress to the pump cylinder, and the vacuum produced in the condenser is increased.

Between the condenser and the air pump an ejector is provided, which consists of a suction box, into which the exhaust from the condenser flows on its way to the air pump. Opposite to the neck of the ejector or discharge pipe is a steam jet screwed into a flanged pipe, passing into the suction box. It has been found by experiment that with an ejector pipe having a discharge neck of 2 inches diameter at the throat, a steam jet of $\frac{1}{8}$ inch diameter at the narrowed part, conically diverging to a diameter of $\frac{1}{4}$ inch at the exit, supplied with steam at 110 pounds pressure, and with a vacuum at the suction of the air pump of $25\frac{1}{2}$ inches of mercury, a vacuum is obtained in the condenser of 26.9 inches, or a gain of 1.4 inches vacuum. With $\frac{5}{16}$ inch jet at the narrowest part, conically diverging to $\frac{3}{8}$ inch at the exit, with 72 pounds of steam pressure, and the same vacuum as before at the air pump suction, *i. e.*, $25\frac{1}{2}$ inches, a vacuum is obtained of 29 inches in the condenser, this being a gain of 3.5 inches vacuum. It is also possible to allow a considerable amount of water or air to pass through the ejector without seriously interfering with its efficient working.

With this device applied to a condenser and air pump the condenser is placed three or four feet above the level of the suction of the air pump, and in such a position that the water of condensation shall flow by gravity down one pipe to the pump, while the air and water vapors are sucked from another part of the condenser through a separate pipe by the vacuum intensifier or ejector, so that little or no water shall pass into the ejector. Under these conditions the ejector deals solely with the air and water vapor, and is, if necessary, capable of dealing with the water of condensation from the cylinder drains and the like. The intensifier has been found to work best with a nearly vertical position of the jet and discharge neck, to prevent accumulation of water in the suction box. In the apparatus described the dis-

charge pipe is bent through an angle of about 60 degrees. Provision is made for connecting drain or other pipes to the suction box, steam to the steam jet being led in by a pipe connected to the ejector. The supply of steam to the jet is controlled by an ordinary valve in the pipe or by a special adjusting nozzle.

In some cases it has been found advisable, in order to obtain the best results, to thoroughly mingle the discharge of air and vapor from the intensifier with the water of condensation on its passage to the air pump, and to use a small auxiliary condenser for condensing the vapor and cooling the water before they enter the air pump. The vacuum intensifier may be used in conjunction with jet condensers of the type with separate air and water pumps, the intensifier being placed between the condensing chamber or pipe and the air pump.

DESTROYERS (BRITISH).

The publication of the short but instructive Parliamentary paper which gives particulars of the new torpedo-boat destroyers, raises again the question whether the Admiralty has not committed a serious mistake in preparing the specifications for these boats. The return in question, which we append to this article, gives the speed, coal consumption, and average air pressure in the stokehold on full-speed trials. The vessels dealt with are those launched more recently, and the figures therefore relate to the class of heavier craft which were designed to satisfy the popular cry for safety, which was occasioned by the wreck of the *Cobra*. Out of the nineteen vessels included in the list, two have not yet completed their trials; whilst two more, the *Velox* and the *Eden*, are fitted with steam turbines, and therefore belong to a class different from the others.

The *Velox* was not built on the same contract conditions as the other craft, and is said to be of a lighter scantling—something between the old thirty-knot boats and the last twenty-five and a-half knot vessels. It will be noticed that the consumption of coal per indicated horsepower hour is not given in the return for the two turbine vessels—a circumstance fully and satisfactorily

accounted for by the fact that indicator diagrams naturally cannot be taken from steam turbines. The coal used per hour is, however, stated, and from this we can draw some conclusions which may be more or less near the actual facts. We may take the standard of 7,500 indicated horsepower, and suppose the coal consumption to be equal to 2 pounds per indicated horsepower per hour. In that case the total fuel burnt would be 6.7 tons per hour. It will be seen by the return that considerably more than this quantity was consumed; and therefore, on the 7,500 horsepower standard, more than 2 pounds of coals were burnt per indicated horsepower per hour. This is a proportion in excess of the best results obtained with the vessels with reciprocating engines, although only three Yarrow boats were under the 2 pounds.

On the trial of the *Welland*, when she made an equal speed to the *Eden*—26.2 knots—the engines developed 7,766 indicated horsepower. If we increase the supposed power of the *Eden's* turbines from the imaginary 7,500 to this figure, the coal per unit of power would naturally be reduced; but even then the consumption at 2 pounds per indicated horsepower hour would be under 6.9 tons, whereas it was actually 7.45 tons. It is, of course, quite possible that the *Eden*, although a somewhat smaller vessel, needed more power than the *Welland* to drive her at an equal speed; but in that case, supposing both hulls to be equally well designed, we might anticipate a lower propeller efficiency. On the other hand, the *Eden's* boilers may have been less efficient than the *Welland's*, and this might account for a higher fuel consumption. Both vessels have, however, Yarrow boilers. In any event, the evidence is only presumptive; but in the case of a new type of machinery, such as the steam turbine, presumptive evidence is not without interest.

Out of the remaining fifteen vessels dealt with in the return, two—the *Derwent* and the *Waveney*—are somewhat smaller than the rest, being each 220 feet long by 23 feet beam; whilst the others are 225 feet long and 23 feet 6 inches wide. It will be seen by the return that the speeds of all these vessels—excluding the turbine boat *Velox*, which made 27.1 knots—varied be-

tween 26.2 knots—obtained by the Yarrow boat, the *Welland*—and the 25.5 knots of the *Dee*. The other turbine boat—the *Eden*—it will be noticed, tied with the *Welland* in steaming 26.2 knots. The former is 5 feet shorter and 6 inches narrower than the latter.

Perhaps the most instructive figures in the return are those giving the amount of forced draft needed on these trials. In this feature there were wide divergences: for instance, the *Blackwater*, constructed at Birkenhead, required on her full-speed trial an average pressure in the stokehold of 5.3 inches of water. On the other hand, two of the Yarrow boats only needed an air pressure equal to 1.6 inches of water. Although the speeds are, in some cases, rather better than those which have already been published, yet they are moderate, not to say low, compared with those of earlier vessels of the same class, both in British and foreign navies; notably the latter. There is, of course, a reason for this, and the reason is fairly well known. After the *Cobra* disaster, the Admiralty, yielding, as we have intimated, to popular clamor—supported by the voice of certain Admirals not experts in naval architecture—determined to increase the structural strength of torpedo craft to a very considerable extent.

The specification for the new boats—those dealt with in the return—was therefore made more stringent; and, beyond the additional weight of metal in the scantling, high tensile steel was largely substituted for the mild steel used in the earlier boats of the 30-knot class. The alteration in the nature of material alone would allow of a reduction of weight equal to 15 per cent. It should be stated that the newer destroyers are larger than the old ones, being about 18 inches to 3½ feet wider, 10 feet to 15 feet longer, and of considerably greater draught than the majority of the former craft. This made them from 200 to 250 tons larger, their displacement being 540 to 550 tons.

The engine power of the new boats had to be higher to drive them even at their lower contract speed. In the older 30-knot design there was generally about 6,000 horsepower; in the newer vessels it is 7,500. The engines in the latter have been strengthened, larger bearing surfaces being given, and the working parts

increased in section generally in the ratio of 10 to 12 of the stresses allowed. The conditions of trial have been made far more exacting in regard to the load. The 30-knot boats had to carry 35 tons, but this was increased to a standard of 125 tons with the 25½-knot vessels last ordered. This standard was not a fixed quantity, but depended upon the fuel economy of the engines. An allowance of 2½ pounds of coal per indicated horsepower per hour was made, and for every increase of one-tenth of a pound over this 4 tons extra load had to be carried. On the other hand, for each reduction that could be effected of one-tenth of a pound per indicated horsepower hour below the 2½ pounds, the load was lightened by 4 tons. In regard to the power developed, it was specified that the estimated horsepower ought not to be exceeded for getting the contract speed by more than 5 per cent., but that 1 ton of extra bunker coal should be carried for every 100 horsepower beyond the guaranteed figure. The speed trials were to be of four hours duration with 125 tons, including coal, guns, provisions, stores and crew; the guaranteed speed being maintained for the last three hours of the trial.

The armament in the larger and newer vessels is similar to that of the previous boats, so there is no increase in the offensive qualities, excepting that the guns are now carried at a greater height—no doubt a military advantage. Against this we have the very great reduction in speed—in torpedo craft one of the first elements alike of offense and defense. In regard to the important question of cost, the 31-knot boats might be put down at an average of £60,000 each; the new vessels will cost about £75,000 each.

So far, it will be seen, we have in these most recent destroyers vessels which, when compared with their forerunners, are slow, costly, heavy and restricted in radius of action. On the other hand, they are strong, large and stable; and the raised forecastle included in the design must be considered. The question is, Which design gives the balance of advantages? The ruling factors being the antagonistic qualities of speed and strength. We will, however, consider the elements of design in the order we have named them, but reserving speed and weight till the last.

Were the money question left out of account, weight would not be a disadvantage if it did not involve loss of speed, or the alternative of additional engine power; we will therefore reserve this point, and pass on to consider radius of action. The Japanese destroyers of 31 knots carry 96 tons of coal in their bunkers, the new 25½-knot British boats carry 120 tons as a standard. At a cruising speed of thirteen knots the Japanese craft would need between 460 and 470 indicated horsepower, whilst the British vessel at the same speed would need between 725 and 735 indicated horsepower. If we take the mean in both cases, and allow 2 pounds of coal per indicated horsepower per hour, we find that the one vessel would need 930 pounds an hour, and the other 1,460 pounds per hour. The Japanese boat would, therefore, steam for two hundred and thirty-one hours, or about 3,000 miles on her bunker coal; whilst the British vessel would be able to steam but one hundred and eighty-four hours, and cover not quite 2,400 miles.

In the extended use to which destroyers are now to be put, with the longer voyages entailed, habitability becomes an important feature, and here size comes in. In the present designs, however, the gain is almost wholly, if not wholly, to the officers, the crew having, in most designs at any rate, the same accommodation as in the older boats.

An examination of the figures in the return just published bear testimony to the difficulty contractors had in filling the onerous conditions laid upon them when making the comparatively moderate speed of 25½ knots. It is true the Yarrow boats did extremely well, standing well first amongst those tried in regard to speed, economy and forced draft. The performance of these boats, however, is altogether exceptionable, and doubtless is largely to be attributed to the remarkable results obtained with the Yarrow boiler, which, by the way, appears to do equally well in larger craft, as shown by the recent voyages of the *Medea*.

If, therefore, we put aside the exceptional Yarrow boats, and glance at the results of some of the other trials, we can form some idea of the difficult task the contractors had set for them.

As stated, the *Blackwater* had to blow until there was a pressure in the stokehold equal to 5.3 inches of water before she could get her contract speed. It is almost a wonder that the coal kept on the bars, although in early days Sir John Thornycroft blew much harder than this, as an experiment—to 7 inches, if we remember rightly; but that was with a different form of grate and thicker fire. Three other boats from the same yard appear to have experienced great difficulty in getting through. The *Foyle* needed an air pressure of 4.4 inches on the water gauge and 2.79 pounds of coal per indicated horsepower hour—an economy that might have been considered good some years ago, but is not up to modern standard. As might be expected, the Yarrow boats, which had the lowest air pressure for draft, had also the best fuel economy, whilst the four boats that blew hardest burnt the highest proportion of coal.

There is no need to pursue the subject further; the results given speak for themselves. The position is that, yielding to pressure that, conceivably, may have been prompted by legitimate caution, but seems much more likely to have been due to scared ignorance, the more recent destroyers have been so strengthened that their expense, both at first cost and for upkeep, has been largely increased, and their powers of offense and defense have been greatly lessened.

The building of these extremely high-speed craft, in which a light hull is a necessity, has been developed and brought to a high state of perfection by certain engineering firms who have devoted themselves exclusively to this class of construction. The work differs essentially from that of larger and more substantial vessels, requiring special knowledge on the part of the designers, special skill on the part of workmen, and special appliances in the yard. To expect builders of heavier craft to construct a destroyer on lines familiar to them is to court failure. These craft have a separate and necessary place in modern warfare. Although the destroyer, properly designed, has been proved to be an excellent sea-going vessel, to attempt to make it into a cruiser is to remove it from its field of usefulness; but the pres-

ent tendency is in that direction. Size is essentially a limiting condition in the work the destroyer has to do. Experience has shown that 30 to 31-knot boats can be so constructed on the old scantlings as to be safe at sea; but they must be designed by competent naval architects experienced in this special type of construction. To pile up material may simplify the task for those who are unlearned in the proper design of these craft—however competent they may be as producers of battleships, cruisers or merchant vessels—but the efficiency of the Navy must not be sacrificed to these considerations. The conventional rules of the science of naval architecture are not alone sufficient for the task; they need supporting or correcting by experience. We append the return to which we have referred above:

DESTROYERS BUILT AND LAUNCHED SINCE JANUARY 1, 1902, FOR HIS MAJESTY'S NAVY.

Names of destroyers.	By whom built.	Speed obtained on full-speed trials. Knots.	Consumption of coal per horsepower on the high-speed consumption trials.	Average air pressure in the stokehole on the full-speed trial.
Velox (turbine)	Hawthorn, Leslie	27.1	*7.35	3.1
Erne	Palmer's Company	25.6	2.25	2.5
Derwent	Hawthorn, Leslie	25.7	2.24	2.8
Foyle	Laird Brothers	25.6	2.79	4.4
Eitrick	Palmer's Company	25.6	2.33	2.6
Eden (turbine)	Hawthorn, Leslie	26.2	*7.45	3.3
Waveney	Hawthorn, Leslie	25.6	2.19	3.2
Ilchen	Laird Brothers	25.6	2.46	4.3
Exe	Palmer's Company	25.6	2.11	2.4
Arun	Laird Brothers	25.7	2.68	4.4
Cherwell	Palmer's Company	25.6	2.34	2.7
Usk	Yarrow and Co.	26.1	1.9	1.6
Blackwater	Laird Brothers	25.7	2.62	5.3
Dee	Palmer's Company	25.5	2.28	2.6
Teviot	Yarrow and Co.	25.9	2.07	2
Kennet	Thornycroft	Trials not yet carried out.		
Jed	Thornycroft			
Ribble	Yarrow and Co.	25.8	1.57	1.6
Welland	Yarrow and Co.	26.2	1.65	1.8

* Tons per hour total.

—"Engineering."

THE "TRAIN" OF FLEETS (FLEET AUXILIARIES.)

In an article in "Le Yacht," entitled The Military Power of Modern Fleets and Those of the Past, M. Guilloux wrote, May 28, 1898: "The causes of the relative inferiority of the fleets of today, compared with the wooden fleets at the end of the last century, are principally the substitution of steam for sails as a motor, the excessive complications of the modern warship and the numerical weakness of the crew."

About the time when these lines were published the Japanese and Russians laid down the vessels which are taking part in the fight of today.

Steam engines of greater and greater power for carrying the same tonnage have continued to consume more and more coal, while their cost per horsepower per hour has not decreased in the last seven years; auxiliary machinery has been multiplied; but the number of the crew has scarcely increased.

The battleship, frequently obliged to replenish its coal and munitions, to clean its steel hull, which fouls quickly, incapable without stoppage and by its own means to repair serious accidents to its motor power, is no more a self-sustaining structure. It would at best only satisfy the strategist who foresaw a strife in European seas in close touch with numerous and well equipped bases of support.

Armored ships with less elevation above the water and provided with eight to ten days' supply of coal then composed the new squadrons of the great powers. To the distant stations were sent old warships, old unprotected cruisers or armored gunboats. These conditions have now been wholly changed. To-day the United States and Japan possess armored squadrons as powerful as those of England and ourselves.

No nation, with the exception of America, has a complete naval station in the West Indies or in the North Atlantic. The most powerful military ports, the largest number and the best dockyards of the extreme orient are in the hands of the Japanese.

England, and following her, France, Russia and Germany, have increased the steaming distance of their new battleships to 6,000 miles at 10 knots, but, practically, this is only about one-third the distance from Toulon to Port Arthur and scarcely

twice the passage across the Atlantic. Nevertheless, these distant stations are the theater of the naval wars of the present and the future.

The necessity for Russia to send to the extreme orient a supporting squadron of powerful units illustrates forcibly the problem of replenishment at sea; and this problem, which Suffren solved when he made a campaign of two years with his wooden fleet without stopping at a naval station or in a port of repairs, presents itself to the squadron of Rojetwensky as a question of life or death.

In order to live, let us say, a modern fleet must be able to replace the coal consumed by its engines; the ammunition discharged from its rapid-fire guns, perhaps its whole supply in a single engagement; and the wounded or sick men of a crew just sufficient to meet the absolute essentials of a warship in action. The fleet must repair the accidents to motive apparatus and to the auxiliaries, then care for the sick and the wounded, discharging them at a port as early as possible, and, finally, a siege may necessitate special equipment.

These services, which may be called rear service, are admirably organized in armies, performing these functions in successive steps from the firing line to the headquarters, by means of wagons and baggage trucks, in entire trains. Provisions, coal for the thermal machinery of the campaign, which is the soldier, and munitions are replenished from the rear to the front in successive stages, while the health service acts from the front to the rear. We now begin to realize that the modern navy has analogous needs.

A single power, Austria, has a "Fleet Train" nearly completely organized. This "*train*" is composed of two parts; first, of special vessels constructed for a definite use: The *Pelican*, of 4,000 tons and 18 knots, the "mother ship" of the torpedo boats; the *Cyclops*, of 2,150 tons, a workshop; the *Pola*, a transport for siege material, blockading means, telegraphs, &c.; the *Salamander*, an old ironclad, for placing mines.

The replenishment of water, coal and ammunition is still, as in most of the navies, left for the auxiliary transports and the requisitioned merchantmen.

The English, and quite recently the Americans, have decided

to construct special colliers, mounted with special apparatus for recoaling at sea. The Temperley apparatus, for a long time the favorite of the British Navy, and tried in ours on the *Japon* in 1886 to 1899, seems to be now replaced by the Spencer-Miller apparatus. The first necessitated the close proximity of the two vessels and could not be used except in a quiet sea; the second gives good results even in a rather heavy sea and permits the replenishing of vessels while towing, or from the towing to the towed boat. The Miller apparatus can discharge up to 40 tons an hour. It can also be employed for the transportation of ammunition. The new American cruisers, the *Erie* and *Ontario*, are to have a displacement of 5,000 [12,000] tons with 16 knots speed, and are to cost 6,200,000 francs [$1,250,000] each. The United States has transformed an old merchant steamer (*Creole*) into a hospital transport, and the famous dynamite cruiser *Vesuvius* into a repair ship. This latter will probably later be displaced by a more modern vessel. [*Vulcan*, ex *Chatham*, was a repair ship, not *Vesuvius*.]

England has two torpedo transports fitted with a complete workshop: the *Hecla*, of 6,400 tons and 11.7 knots, launched in 1877, and the *Vulcan*, of 6,620 tons and 20.2 knots, launched in 1889.

She has this year placed on the ways two colliers of 12,000 tons, fitted with new coaling apparatus. It appears, however, that these vessels are destined for the Mediterranean and Channel fleets. Two smaller colliers are to be attached ultimately to the China squadrons.

Russia has an excellent transport workshop, the *Okean*, of 12,000 tons and 18 knots, which carries, like the *Yenissei* and *Amoor*, an entire outfit of materials of defense—torpedoes, mines, with their apparatus for anchoring, apparatus for cutting electric cables, etc. In times of peace the *Okean* serves as a school for mechanics. Her battery of boilers, being composed of all the types actually used, is a veritable museum.

We have seen that Russia does not possess any colliers. The vessels of her volunteer fleet form good and rapid transports of provisions and materials: they can also be transformed into hos-

pital ships; but for coal it is necessary in war times to buy vessels at high prices from German and Dutch companies. This improvidence had a precedent in the United States in 1898, and it must be said that the Americans emerged from the difficulty admirably. In France we must say in truth that we have but a single vessel of the "train of the fleet"; the *Foudre*, workshop transport, with 20 knots speed, serves also for the replenishing of the torpedo-boat supplies and for the transport of vedettes. It is thought to utilize her for submarines also.

Some of our old transports to Cochin China have received special missions: the *Bien-Hoa* and the *Vinh-Long* are replenishers for ammunitions; the *Gironde*, replenisher of material and torpedoes; the *Mytho*, replenisher of provisions; but we have no colliers. It appears that our navy counts on cargo boats to render this service. For this there might also be utilized the old transatlantic cargo boats and vessels of the merchant marine of less than 18 and more than 16 knots, some of which have spacious holds. In others many bulkheads and fittings would need to be torn out to make the necessary hold spaces and hatchways.

If we do not see the absolute necessity of reconstructing the transport vessels, we believe it is indispensable to put on the ways a half dozen colliers of 5,000 to 6,000 tons, provided with improved apparatus for loading and transporting.

The navy, which has only merchant ships for these services for replenishing, is as foolish as the army which depends only on the wagons of the peasants for transporting its provisions, ammunitions and baggage. The solution of a problem may be found once, by luck, but we should place dependence only in foresight and preparation.—"Le Yacht."

FOUNDRY PRACTICE WITH COPPER AND ITS ALLOYS.*

By W. J. Reardon, Foreman, Brass Foundry. The Westinghouse Machine Company.

Copper and its alloys are very important materials from the standpoint of the electrical engineer, and since a large part of

*A paper read before the Electric Club.

these materials must be shaped by casting, the foundry practice in connection with them becomes important.

The process of casting is apparently simple: Copper is not hard to melt, and, when melted, it is not difficult to pour the fluid mass into a properly shaped receptacle. Sad experience has, however, shown the foundryman that good results cannot be obtained by any hap-hazard methods.

The first requirement is that the copper must be heated to exactly the right temperature. If the heating be prolonged and the metal brought to a bright red heat it becomes "soaked," as it is called. After being poured there is a period of quietness, and all seems well; suddenly there is a small explosion; the sand is blown from the flask and the metal at the gate flies in all directions. When the casting is examined it is usually found to bear no resemblance to the pattern. If the heating be incomplete and the temperature too low the action will be somewhat different, but the result will be no more satisfactory. There will be no explosion, but instead the sand on the copper rises and breaks up; the metal at the gate swells and the liquid copper continues to ooze out for some time. When examined the casting is found to be full of blowholes, their number depending upon the temperature at which the metal was cast. The effect of overheating or underheating are the same, regardless of the fuel employed—whether, coal, coke, oil or gas.

The second requirement is that the sand must have a proper temper, neither too wet nor too dry; experience alone can teach one how to best fill this requirement. If copper is poured into green sand the casting will be full of blowholes. On the other hand, dry sand will not hold together. The foundryman's hardest problem is to produce castings free from blowholes. Sometimes a casting will look all right on the outside, but blowholes are found inside when the piece is turned up. Every job requires instructions from the foreman about the temper of the sand, position of the gates and risers.

At the Westinghouse foundry castings are now being made without difficulty which range in size from one ounce to five

hundred pounds. The difficulties were overcome by observing the following rules:

1. Heat to exactly the right temperature.
2. Have the sand at the proper temper.
3. Melt the copper quickly.
4. Keep the metal covered at all times.
5. Never let the metal stand in the furnace when once ready.
6. Add a small amount of silicon copper.

In mixing and melting brass a few simple rules should be observed.

1. Weigh carefully.
2. Melt quickly and uniformly.
3. Prevent volatilization as far as possible.
4. Pour at exactly the right heat.

The first rule may seem needless, but bad results are often traceable to careless weighing.

Pouring at the proper temperature is of the utmost importance. At the present time the temper is estimated by the naked eye, the experience of the melter and skimmer being relied upon to decide when the metal has reached the temperature proper for the alloy and the character of the job to be done.

The use of the pyrometer in the Westinghouse foundry for the determination of temperature has not been attended with great success, chiefly on account of vibration. In other places the instrument has proven unsatisfactory because of its sluggishness in responding to changes of temperature.

A bearing metal resembling glyco-metal has been used in the Westinghouse foundry which gives excellent results. It is composed of copper, tin, lead and zinc. This alloy is difficult to make because of the tendency of the lead, whose specific gravity is high, to settle to the bottom. There seems to be no amalgamation of the lead with the proportions of copper and tin used. To check the precipitation of lead the bottom of the casting was chilled with running water, immediately after pouring. This gave good results in small bearings, but did not with large. Finally methods of mechanical mixing were adopted which gave

excellent results both in casting and on test. The test showed remarkably low friction and small wear.

Another alloy was made up of the same elements, but a different scheme of mixing was adopted. The mixing was divided into two steps; the first consisting of making an alloy low in copper, and the second, mixing this intermediate alloy with copper. The intermediate alloy was made by melting the copper first under a charcoal cover and then adding lead, then zinc, then tin; overheating being carefully avoided. This intermediate alloy was poured into ingot molds. After cooling, it was put into melted copper. The resulting alloy could be cast in sand and withdrawn while red hot without showing any signs of lead sweating out, although the temperature of the casting when withdrawn was far above the melting point of lead. The temperature must be watched very carefully, as a slight excess causes the lead to segregate, and, chiefly for this reason, the alloy cannot be made in a Swartz furnace.

In the melting of alloys it is customary to melt first the constituents having the highest melting point, then add the others in the order of their melting points, the one with the lowest melting point being added last. Sometimes, however, metals will alloy at a temperature below that of the melting point of some of the constituents. For instance, a brass may be made by first melting zinc, which melts at about 800 degrees Fahrenheit, then taking the crucible out of the fire and adding solid copper whose melting point is about 2,000 degrees Fahrenheit.

A singular point about alloys containing lead and tin is that lead will separate out if the percentage of tin is considerably in excess of that of lead, but by decreasing the percentage of tin and increasing that of lead the larger proportion of lead alloys without difficulty.

There is an alloy known to the trade as plastic bronze, which contains 20 per cent. of lead. This large amount of lead is probably held by a small amount of tin and nickel. The alloy gives excellent results.

In the Westinghouse foundry, the molding machines are arranged in two rows, one on either side of the middle aisle. The

conveyors, one over each row, carry the sand from spouts which discharge into the flask. The operator, by opening a gate in the spout, allows sand to pour into and fill the flask. When ready for pouring the flasks are set in line along the grating, and as soon as the metal has been poured and is cool enough, the flasks are dumped on this grating, through which the sand passes to an automatic riddle. The riddle catches and throws out all scrap, nails, etc., and the sifted sand is carried by belt conveyor to a set of rolls. After passing through the rolls it falls into a self-dumping pan where a certain amount of water is added, bringing it to the right temper. An elevator takes the sand as it is dumped from the pan and carries it to the overhead conveyor to be used over again.

The sand gave no trouble when the distance handled was fifty feet or less, but after a longer haul it was left in such condition that it would not hold together when the hot metal struck it, but washed away like so much powder, losing entirely the shape of the pattern. When examined under the microscope this sand was found to be entirely disintegrated; the grit and the loam was separated, and formed into globules that would not stick to each other. The difficulty was overcome by passing the sand, after being discharged from the flask and riddled, between a set of chilled rolls. These rolls have to be kept in good shape, for, as soon as they became worn, the sand returned to the disintegrated condition.

A STUDY OF ALLOYS SUITABLE FOR BEARING PURPOSES.*

At first glance it may appear an almost hopeless task to even surmise which alloy is best constituted for such service; but upon closer examination we find that but few metals are available. They are as follows: Copper, tin, lead, zinc, antimony.

It is true that other metals and metalloids may be introduced in varying small proportions, either with or without some material advantages, but the above five metals constitute the basis which may be used for the so-called anti-friction alloys. The

* Journal of the Franklin Institute, July-October, 1903.—Extracts from an Article by G. H. Clamer.

combinations of the above metals, which today figure in service for this purpose, may be classed under two heads: *White metals*, *Bronzes*.

White Metals.—Lead, antimony; lead, antimony, tin; tin and antimony; tin, antimony, copper; tin, antimony, copper, lead; zinc, tin, copper; zinc, tin, antimony; zinc, tin, antimony, copper.

Bronzes.—Copper and tin; copper, tin and lead; copper, tin, lead and zinc; copper, tin, zinc; copper, zinc, lead.

It will, no doubt, be interesting to have before us the essential points to be considered in this connection: Composition, structure, friction, temperature of running, wear on bearing, wear on journal, compressive strength, cost.

It is an utter impossibility to have one alloy reach the pinnacle of perfection in all the above requirements, as I shall later demonstrate; for example, the metal showing the slowest rate of wear may have the highest coefficient of friction, or the metal with the lowest coefficient of friction may have the greatest rate of wear, etc.

If it were possible to reach mechanical perfection in the adjustment of bearings it would be of little consequence what alloy or metal were used, providing the same had sufficient strength to support the load without deformation. If perfect adjustment were possible, we would have at no time metal in contact with metal, but simply metal in contact with oil, the friction would be essentially fluid friction and abrasion due only to the wear of fluid against solid. But, unhappily, such a state of perfection can scarcely be reached, where end thrusts, lateral motion, reversal of direction of motion, etc., are continually encountered. Such being the existing state of affairs, the above-tabulated qualifications must be studied and each balanced against the other according to its importance.

First and foremost is the qualification that the alloy have the best composition, all things considered, to make the bearings—on this depends all the following essentials.

On the composition in a great measure depends the structure. It is true that heat treatment and certain manipulation may affect

the structure of the same compositions, but this effect is more particularly upon the size of crystals, &c. What is here meant by structure is the characteristic structure of a certain combination of metals; for example, the binary alloy, antimony and lead. This consists of crystallites of lead imbedded in a matrix of eutectic if the percentage of antimony be below thirteen, and, if above thirteen, consists of eutectic and free crystals of antimony. It has been shown that a successful bearing alloy must consist of at least two structural constituents—one hard constituent to support the load and one soft constituent to act as a plastic support for the harder grains. Generally speaking, the harder the surfaces in contact the lower the coefficient of friction and the higher the pressure under which "gripment" takes place.

It would seem for this reason the harder our bearing alloy the better. It was with this idea in mind that alloys of copper and tin were so extensively used in the early days of railroading. A hard, unyielding alloy for successful operation must, however, be in perfect adjustment, a state of affairs unattainable in the operation of rolling stock. In order to obtain a proper adjustment of bearings when first applied in service Mr. Hopkins many years ago introduced his lead-lined bearing. The practice of lining bearings has now become almost universal in this country. But notwithstanding that the bearing by this method obtains a good seat on the journal, the adjustment is constantly disturbed, and the bearing proper must have a certain plasticity of its own to avoid heating when called into service to support the load.

In order to secure this plasticity lead was introduced into the copper and tin alloy, and with excellent results, but this I will treat more fully later.

The third consideration in connection with our determination of the most suitable alloy is friction. Friction is dependent upon the composition and structure of the alloy. As stated, generally speaking, the harder the metals in contact the lower the co-efficient of friction; thus the class of bronzes have a lower coefficient of friction than the babbitt or white metals. At the same time, the harder the metal the greater the liability of heating, because of the absence of plasticity (the property a metal

has of molding itself to irregularities on the journal, and the consequent maintenance of a large area to carry the load). A hard, unyielding metal under the above conditions will cause a concentration of load upon one or more high spots, and so cause an abnormal pressure per square inch on such areas, with the result that rapid abrasion and heating soon result. A hard, unyielding bearing is a theoretical delusion, much to be desired, but impractical of application.

Structure of the alloy plays an important part, as hard spots caused by oxidation, etc., frequently cause an irritation of the journal with a simultaneous production of abnormal friction and temperature.

Temperature of running is of importance for determination, in so much that the amount of oil consumed is greater, the higher the temperature, but at the same time the lower the friction, providing the bearing is running under normal conditions. This is true only when comparing the same bearings under different temperatures, because a higher temperature may be caused by increased friction. Generally speaking, the bronzes under the same conditions of pressure and speed will operate at a lower temperature than the softer metals, all things being equal.

Wear of Bearing.—It is quite remarkable the relation existing between composition and wear. This presents a wide field for research—a field almost unexplored. High-priced compositions are being used, which have but little resistance to wear compared with cheaper compositions, and low-priced alloys are in service that are not cheap at any price. But very little data is to be had on this score, for the reason that such tests in service require a great deal of time, and a satisfactory laboratory machine has not until recently been designed. A machine which the writer has used for the past two years has given good satisfaction, and will be described shortly.

Wear on Journal.—Composition of the bearing has a decided effect upon the wear of the journal; but whether the difference in the rate of wear is due directly to the composition is a disputed point—no positive proof to this effect is attainable. It is generally conceded that the soft-metal bearings cause a marked

decrease in the life of journals. Now, as to whether this is due to the imbedding of grit on the bearing surface, with the consequent formation of a lap, or to the fact that the metal itself has a dragging nature, I am not prepared to say.

Compressive Strength.—A test of the compressive strength of alloys intended for use as bearings is of importance in indicating—(1) If the alloy is hard enough to support the load without deformation. (2) If the alloy is brittle and will split under effects of pressure. (3) If it is sufficiently plastic to reasonably suppose it will run cool under aggravated conditions.

Now, having briefly discussed the qualification of the bearing metal, let us take up the various combinations of metals as previously classified and study their characteristics.

Lead and Antimony.—These metals will alloy in any proportion, with increase of antimony the alloy becoming harder and more brittle. The combination of these two metals, however, which alone is exempt from segregation, is that of the eutectic mixture, which, according to various authorities, has been found to be approximately: Lead 87 per cent. and antimony 13 per cent. Alloys with less than 13 per cent. show, upon microscopic examination, to consist of dendrites of pure lead embedded in a matrix of eutectic. The structure of the alloy with the eutectic composition shows no segregated metals or alloys, and has a laminated structure characteristic of all eutectics, consisting of laminæ of lead and laminæ of antimony.

With above 13 per cent. of antimony free crystals of antimony appear, and, if the alloy is allowed to cool slowly, they rise to the surface, owing to the very low specific gravity, namely 6.5, as compared with the specific gravity of the eutectic, which is 10.48.

The melting points, as given by Stead, are for the segregated antimony about 615 degrees centigrade, and for the eutectic 247 degrees centigrade. It will be noted that the temperature of the eutectic is 78 degrees below the conceded melting point of lead—the most fusible constituent; therefore, in an alloy below 13 per cent. antimony, the lead crystallizes out of the still fusible

eutectic in the form of so-called and well-known "Fir Tree" lead.

Alloys containing 10 per cent. antimony show upon the surface of a slowly-cooled ingot the eutectic spherules and lead crystals.

Alloys containing less than 6 per cent. antimony show only lead crystals upon the surface, owing to the predominance of those which solidify over the eutectic.

According to Charpy, an antifrictional alloy should consist of hard grains, which carry the load imbedded in a matrix of plastic material, to give it the property of molding itself to the journal and its irregularities without undue heating. Such a condition is met in the alloys above the eutectic composition; but with the increasing antimony the alloys become more brittle, and above 25 per cent. are unsafe in service for this reason.

Charpy further claims that alloys between 15 per cent. and 25 per cent. are best constituted for bearing purposes. I cannot quite agree with this, however, as the alloys containing below 13 per cent. antimony can likewise be said to consist of hard grains (the eutectic imbedded in lead), and it has been my experience that although the friction may be higher in such alloys, the wear is greatly diminished, and where pressures are light, causing no deformation, this is a great advantage. I have seen many instances in service where alloys between 15 per cent. and 25 per cent. were greatly inferior to alloys between 8 per cent. and 12 per cent., owing to their frequent renewal due to wear.

Lead is the best wear resisting metal known, and with increasing antimony or increasing hardness and brittleness the wear becomes more marked. This is due to the splitting up of the harder particles.

The friction, as we may naturally expect, becomes less with increase of antimony, and the temperature of running likewise diminished when running under normal conditions; but the harder the alloy the more difficulty is experienced in bringing it primarily to a perfect bearing, and the greater the liability of heating through aggravated conditions. The wear on the journal one would naturally expect to be decreased with increasing

hardness; but this journal wear is in all probability not due so much to the alloy directly as it is to the fact that the softer metals collect grit, principally from the small particles of steel from the worn journal, and, acting as a lap, cause rapid wear. With the harder metals these particles are worked out without becoming imbedded.

The cost of the above alloy is the least which can be produced. It can be used in many services where higher-priced alloys are being relied upon mainly for their high cost. It is one of the greatest extravagances of large industrial establishments to use goods which are too good for certain uses, and even perhaps unsuited, under the supposition that they must be good because they paid a good price for them.

Lead, Antimony and Tin.—I do not wish it understood that antimony-lead is the cheapest alloy to use under all circumstances, for when high pressures are to be encountered tin is a very desirable adjunct. Tin imparts to the lead-antimony alloy rigidity and hardness without increasing brittleness, and can produce alloys of sufficient compressive strength for nearly all uses. The structure of a triple alloy of this nature is quite complicated and not yet definitely defined.

Besides the existence of various metals in the free state, or in solid solution according to the proportions in which they exist, there is a distinct chemical combination SbSn. The introduction of tin into the finely-crystalline antimonial lead of commerce gives it a coarser grain, due to the formation, no doubt, of the cubical crystals of the above-mentioned chemical combination SbSn. The cost of the alloy increases with increase of tin; but for certain uses, where insufficient compressive strength cannot be gotten by antimony, because of its accompanying brittleness, it is indispensable, and will answer in nearly every case where the tin basis babbitts are used.

Tin and Antimony.—This alloy, with 5 per cent. antimony, is shown to consist of free tin and a matrix of tin and antimony, probably the formula SbSn or $SbSn_2$, as claimed by some investigators. The same is true of alloys containing up to 45 per cent. antimony, when the scattered crystals previously seen are

brought closer and closer together, as in the lead-antimony alloy, until they are in close contact with each other, and probably have formed the compound Sb_2Sn_2. Tin and antimony are seldom used alone as bearing alloys, but are extensively used for so-called Britannia ware, and in equal proportions for valve seats, &c.

Tin, Antimony and Copper.—This combination is what is known as genuine babbitt, after its inventor, Isaac Babbitt, who presumably was the first man to conceive the idea of lining bearings with fusible metal. The formula, for no arbitrary reason, which he recommended is as follows:

Tin, ...	88.89
Antimony, ...	7.41
Copper, ...	3.70

This formula is still considered the standard of excellence in the trade, and has been adopted by many of the leading railroads, the United States Government and many industrial estabments. It is used in the majority of cases where cheaper composition would do equally as well.

According to Behrens and Bauche, who have made extensive examination of this triple alloy, it is made up of rectangular crystals of an alloy of tin and antimony, a whitish bronze forming radial clusters or brittle rods, composed of hexagonal flakes, the mother liquor or matrix being nearly pure tin. The cuboidal crystals are evidently 9 per cent. tin and 1 per cent. antimony, and the rods of whitish bronze 9 per cent. tin and 1 per cent. copper. This is the most costly of all bearing alloys because of the high content of tin.

Tin-antimony Lead-copper.—This quadruple combination of metals I will not venture to describe, as it would no doubt take years of study to fathom the complexity of the metallic combinations here represented. Suffice it to say that lead, although of itself a soft metal, renders this alloy, when added in but small proportions, harder, stiffer, more easily melted, and superior in every way to the alloy without it, and yet consumers will raise their hands in horror when a trifling percentage of lead is found

in their genuine babbitt. This is one of the instances where cheapening of the product is beneficial.

The foregoing represents the more important combinations of alloys of tin and lead basis. These are of far more importance in the arts than the white metals, the main portion or basis of which is zinc.

At various times new combinations of zinc have been proposed, but so far as my knowledge goes, they have not come into popular use for two reasons. First, because of the great tendency of zinc to adhere to iron when even slightly heated. What is technically known as galvanizing the journal is effected under these conditions. Second, because of the brittleness produced under the effects of heat, such as is produced by friction when lubrication is interfered with and consequent danger of breakage. I will not discuss the various combinations of zinc separately, because, as I have already said, they present but little practical importance.

Bronzes.—Bronze is the term which originally was applied to alloys of copper and tin as distinguished from alloys of copper and zinc; but gradually the term "bronze" has become applied to nearly all copper alloys containing not only tin, but lead, zinc, etc., and no sharp lines of demarcation exist between the two.

* * * *

Copper and Tin.—This, according to our general conception of the word, is a bronze only when the copper content exceeds that of tin. According to the proportions in which the metals exist, it has widely-different properties. In general, the tin hardens when present up to proportions of 30 per cent., or perhaps a little over, and when this limit is exceeded, it takes on more and more the nature of tin until pure tin is reached. From a scientific point of view this alloy is one of the most interesting and has attracted the attention of many investigators, who have spent years of study on it, to learn its various properties and explain its constitution. The investigators are Kunzel, Thurston, Charpy, Haycock, Neville and others.

The alloys which interest us most, however, are those which are so constituted as to be adapted for bearing purposes. These would be said to contain from 3 to 15 per cent. tin, and from 82 to 97 per cent. copper. The alloy of tin containing smaller percentage of copper is often used as a babbitt metal, but this comes under the class of white metals, which I have already discussed. Bronze containing above 15 per cent. of tin has been recommended at various times for bearings, owing to its hardness, but very unwisely, for such a bearing assumes mechanical perfection and perfect lubrication. It has no plasticity of its own, and immediately as the oil film is interrupted rapid abrasion and gripment take place, with hot boxes as the result. The very erroneous idea is still held by many, that to resist wear and run with the least possible friction a bearing alloy must be as hard as possible. It is true that hard bodies in contact move with less friction than soft ones; but the alloy which is the least possible to heat and cause trouble is the one which will stand the greatest amount of ill use; by this I mean an alloy which has sufficient plasticity to adapt itself to the irregularities of service without undue wear.

Table I.—COPPER AND TIN, AND COPPER, TIN AND LEAD SERIES.

	Copper.	Tin.	Lead.	Friction.	Temperature above room.	Wear, in grams.
1	85.76	14.9	...	13	50	.28
2	90.67	9.45	...	13	51	.1768
3	95.01	4.95	...	16	52	.0776
4	90.82	4.62	4.82	14	53	.0542
5	85.12	4.64	10.64	18½	56	.038
6	81.27	5.17	14.14	18½	58	.0327
7	75?	5?	20?	18½	58	.0277
8	68.71	5.24	26.67	18	58	.0204
9	64.34	4.7	31.22	18	64	.013

The conditions in all above-described tests were as follows:

Total number of revolutions made..... 100,000
Revolutions per minute..... 525
Size of journal .....3¾ inches diameter, 3½ inches long.
Pressure per square inch, in pounds..... 1,000
Lubrication.....Galena coach oil, fed by cotton waste.

(1.) *Copper 85 per cent., Tin 15 per cent.*—Microscopic examination shows this alloy to be made up of chemically-combined copper $SnCu_3$ dendrites of pure copper, and a large area of eutectic mixture, 73 per cent. copper, 27 per cent. tin, as given by several authorities.

The friction, as naturally expected, is lower than that of any of the following alloys which were tested, they being all softer than the above. The temperature of running, being a factor of the friction, is likewise less. The wear, however, is greatest of all, no doubt due to the large amount of hard, brittle eutectic present (copper 73, tin 27).

(2.) *Copper 90 per cent., Tin 10 per cent.*—This alloy has the same general structure as the alloy of 15 per cent. tin, but differs in the greater amount of free copper and lesser amount of eutectic which it contains.

The friction was practically the same, temperature a little higher than the foregoing, but the rate of wear slower, owing to the smaller amount of eutectic present, and its consequent softness.

(3.) *Copper 95 per cent., Tin 5 per cent.*—This alloy contains, besides the $SnCu_3$, large amounts of free copper and but small amount of eutectic, especially if the alloy is quickly cooled.

Friction and temperature are here again higher, and the rate of wear greatly diminished.

Dr. Dudley, in a paper which he read before the Franklin Institute in 1892, showed the relation existing between the tin and lead content of the copper alloy, and his determinations were founded on actual practical tests. Their relation to the tin content, are summed up in his own words, as follows: "The rate of wear diminishes with the diminution of tin." These determinations, it will be noted, are confirmed by my own work on the subject, and gives us a starting point on which we have based our knowledge for the production of a very efficient bronze for bearing purposes, presently to be described.

Copper, Tin and Lead.—The copper, tin, and lead alloy is now recognized the standard bearing bronze, and in the above-mentioned paper the fact was clearly established that lead introduced

into the copper-tin alloy was a decided advantage; first, because the bearing containing lead was less liable to heat, under the same state of lubrication, etc.; and, second, the rate of wear was greatly diminished. Experiments were made in service which clearly demonstrated the above facts. It will, no doubt, be interesting to note Table II, which represents these results in classified form:

Table II.

Metal tested.	Composition.					
	Copper.	Tin.	Lead.	Phosphorus.	Arsenic.	Relative wear.
Phosphor bronze, standard	79.7	10	9.6	.8	...	1
Ordinary bronze	87.5	12.5	...	...	...	1.49
Arsenic bronze, "A"	89.2	10	...	...	.8	1.42
"B"	82.2	10	7	...	.8	1.15
"C"	79.7	10	9.5	...	.8	1.01
Bronze, "K"	77	10.5	12.5	...	...	.92
	77	8.0	15	...	...	.86

Three points will be noted: (1.) The rate of wear diminishes with the decrease of tin, as above stated. (2.) The rate of wear decreases with the increase of lead. (3.) Arsenic and phosphorus apparently have no bearing on the wearing qualities. My work here again has been but of a confirmatory kind. Taking up the same thread, I began with the alloy of 5 per cent. tin, holding this constant in all following alloys examined, but increasing the lead 5 per cent. each time.

(4.) *Copper 90 per cent., Tin 5 per cent., Lead 5 per cent.*—Microscopically, this alloy shows the presence of pure copper, practically pure lead in mechanical admixture, and the copper-tin eutectic (consisting of copper and crystals of $SnCu_3$). I am not prepared to say if there also exists one or more complicated eutectics; this is quite probable. I have some information bearing on this point, but as a discussion of this will be quite lengthy, will omit it here.

The lead, as naturally supposed, covers but a small portion of the field.

(5.) *Copper 85 per cent., Tin 5 per cent., Lead 10 per cent.*—This alloy shows the same general characteristics as the foregoing, but a larger field occupied by the lead. The lead is clearly seen without etching, and is shown to be held in little pockets or network of copper and tin.

(6.) *Copper 80 per cent., Tin 5 per cent., Lead 15 per cent.*—Microscopically the same as above.

In view of the foregoing knowledge it seemed to be highly desirable to produce an alloy with as much lead and as little tin as possible, not only for the reason that such an alloy is less liable to heat in service, and at the same time show a diminished rate of wear, but also because the two expensive metals, viz: copper and tin, are replaced by a far cheaper metal, lead.

* * * *

The fact was discovered that a certain amount of tin was necessary for retaining the lead without segregation, and also to give the alloy requisite compressive strength, but that a greater amount is exceedingly detrimental. We are able to produce, without difficulty, alloys with 5 per cent. tin and 30 per cent. lead, but were unable to obtain castings containing 30 per cent. lead, if the tin exceeded 6 to 6½ per cent., nor could we produce castings with even slightly above 20 per cent. when 7 per cent. of tin was exceeded. This seemed very strange, as naturally one would suppose if a small amount of tin will hold a certain amount of lead a larger amount should hold still more. The most satisfactory explanation we could find for this is as follows: As I explained when discussing the copper-tin alloy, the same was made up of dendrites of copper, a chemically-constituted alloy of copper and tin and eutectic, the eutectic being made up of laminæ of $SnCu_3$ and laminæ of copper, and being found by analysis to contain 73 parts copper and 27 parts tin, and having solidifying point of approximately 930 degrees Fahrenheit, while the copper solidifies above 1,800 degrees.

Now, as the tin is increased the eutectic is increased, and one can readily imagine that when a large bulk of the alloy must cool down from the casting temperature above the melting point of copper (to 930 degrees), it must necessarily remain a long

while in the liquid state in the mold. The lead, as I have shown, is but mechanically held by the network of copper and tin, and, having a solidifying point more than 300 degrees below the eutectic, has abundant opportunity, owing to its high specific gravity, to liquate to the bottom of the casting, and this, in fact, is exactly what happens; but in the absence of eutectic, or in the presence of but small amount of it, solidification takes place soon after entering the mold, and forms the copper-tin network, which envelops and upholds the still liquid lead. This is evidenced by the fact that such castings may be withdrawn from the sand when still red hot (far above the solidifying point of lead) and yet show no sweating of the above metal.

* * * *

The results obtained by adhering to the above proportions, however, are not entirely what may be desired for every-day practice. The presence of some detrimental impurities or casting at a too-elevated temperature often causes slight segregation. The thought now came to our minds to obtain some means of more rapidly chilling the castings. The casting in iron molds being entirely impracticable for manufacture of many miscellaneous patterns, made us seek for some better means. The thought came, Is it possible to add some element directly to the alloy which will have the desired effect? After going over the whole list of high-melting-point metals, nickel was found to be the only one which answers in a practical way. It unites readily with copper, and the presence of from ½ to 1 per cent. is found sufficient to cause a rapid setting of the cast metal.

* * * *

This alloy is now known in the trade as "Plastic Bronze," and has become a thoroughly commercial article. It has been on the market hardly three years, but has been made in an amount which approximates 4,000,000 pounds. It has been cast in all manner of patterns, weighing from a fraction of a pound to over 1,000 pounds each, and is handled as readily in the foundry as phosphor-bronze, manganese-bronze, or any of the more common alloys. Castings are sharp and clean. It machines readily,

and, in fact, possesses all the qualifications essential for practical purposes.

Having accomplished the production of an alloy containing upwards of 20 per cent. lead, the next object was to test it in the manner of the previous ones, the tin being kept constant at 5 per cent.

(7.) *Copper 75 per cent., Tin 5 per cent., Lead 20 per cent.*—It will be noted that no nickel was used in the test bearings, as it was thought desirable to have no other elements present.

Microscopically the alloy showed the same structure—network of copper and tin, and large area mechanically held lead.

(8.) *Copper 70 per cent., Tin 5 per cent., Lead 25 per cent.*—Same as above.

It will be noted that friction here is apparently little less than above.

(9.) *Copper 65 per cent., Tin 5 per cent., Lead 30 per cent.*—Microscopically examined, a large portion of the field is shown to be covered by lead.

The alloy which we have adopted consistent with proper strength for general purposes and with the best foundry results is: Copper 64 per cent., tin 5 per cent., lead 30 per cent., and nickel 1 per cent.

It will be noted that what is true of the alloys of 15 per cent. lead and under is also true of the high-lead-content alloys, viz: that the rate of wear diminishes with increase of lead, or, in other words, the rate of wear diminishes with the diminishing compressive strength or increased plasticity of the alloy. This alloy has plasticity resembling babbitt metals, and for this reason can fairly be expected to show a less tendency to become heated. This has been amply proven in actual service.

There remain several other classes of bronzes, which, owing to their low cost of production, are largely used. They are alloys of copper and tin containing zinc or containing both zinc and lead. Such alloys as these can be made from miscellaneous junk, and hence the low cost of production.

Foundry and machine tests have been made of a number of these, which brought out the following conclusions:

(1.) Zinc increases the rate of wear.

(2.) Zinc has a tendency to segregate lead.

Table III will be of interest in this connection. Effort was made to keep the tin and lead as constant as possible and replace copper by zinc.

* * * *

Table III.

	Copper.	Tin.	Lead.	Zinc.	Friction.	Temperature above room.	Wear, in grams.
5	85.12	4.64	10.64	...	18½	56	.0380
10	82.27	5.28	10.25	2.07	18½	68	.0415
11	79.84	4.71	10.3	5.44	18½	66	.0466
12	77.38	5.62	11.42	6.54	18½	68	.0472
13	74.28	4.68	10.61	11.04	18½	69	.0846

Conditions same as in Table I.

INGOT COPPER.

The increasing use of electrical appliances has carried with it a corresponding improvement in the quality of copper which is found on the market. As there is no test, chemical or physical, which can at all approach that of electrical conductivity for the determination of the purity of copper, this method of testing has now become standard and widely used. All copper wire used for electrical purposes must pass the requirements of conductivity, and therefore purity, before it can be used, and such copper, be it Lake or electrolytic, cannot be otherwise than good. It will make good brass or other copper alloys. We regret to say, however, that we have found that certain copper producers have been accustomed to take advantage of the fact that only copper wire is tested for conductivity and that ingots and cakes are allowed to go untested. Metal of a quality which would not pass inspection in the billet is, accordingly, accepted in the ingot or cake without question.

Such a condition is especially true of ingot metal, as cakes have to pass the rolling test while the ingot is simply made into brass, and if the quality of this alloy is unsatisfactory the caster is usually censured. It is customary to rely implicitly upon the

reputation of the smelter for the purity of the ingot. Now herein lies the difficulty. All copper smelters have slags produced in their refining furnace in which impurities exist. These slags are reduced in the cupola to metal, which is again returned to the refinery with further concentration of impurities. Copper made from slag metal is much more difficult to refine than otherwise, and the resulting copper ingot is apt to be of somewhat low conductivity, and more or less impure. Realizing that the consumer does not test the ingots, it is customary to put this copper into this particular form and leave the brand to do the rest.

We have recently had many cases of this kind brought to our notice in which the results were unsatisfactory, but the ingot metal and cakes were of the best known brands. A heel of one of the copper ingots forged down under a steam hammer, drawn into wire, and tested for electrical conductivity, gave only 83 per cent. Further investigation proved that the concentration of impurities in the slag was responsible for the condition.

We believe that this condition of affairs exists much more flagrantly in the Lake smelters than the electrolytic, as the latter are constantly on the alert to check any contamination of this kind. The name of Lake copper, however, has become such a familiar word that we are apt to overlook any possible contamination of the material. The smelters' claim is that in ingot metal there is nothing specified in the way of conductivity and that the ingot is Lake copper. To be sure it is, but unless the results obtained from its use are satisfactory, the difference in price which exists between Lake copper and electrolytic must soon disappear and the two be placed on a parity. We believe that it is not imposing a hardship upon the smelter to expect him to furnish as good copper in the ingot as he does in the wire bar. Such a condition, however, has been so difficult to bring about that some brass mills are buying wire bars and cutting them up so that they may be used in the crucible. The day does not appear far distant when all copper, ingot, cake or wire bar, will be uniformly tested for conductivity.—"The Metal Industry."

EFFECT OF IMPURITIES ON COPPER.

Pure copper alloyed with .02 per cent. of lead or bismuth consists of crystals of copper surrounded with a thin skin of lead or bismuth, and is so brittle that it will not roll; in the absence of sub-oxide of copper the presence of .002 per cent. of bismuth is sufficient to make the copper brittle. When .02 per cent. of arsenic, phosphorus or tin, is added to pure copper the copper crystals are surrounded by an eutectic alloy of the two constituents; the alloy can be rolled hot, and is very malleable; the addition of .02 per cent. of antimony or zinc gives a similar structure, but the alloy rolls very poorly; sub-oxide of copper al-o gives a similar structure, but up to 1 per cent. may be present without affecting the malleability of the alloy.

The addition of .02 per cent. of iron, manganese, aluminum or nickel to pure copper does not alter the micro-structure of the metals. Arsenic has the property of neutralizing to a certain extent the injurious effects of bismuth, lead and antimony, but tin, manganese and aluminum intensify the effect of the impurities. So also manganese and aluminum when present to the extent of 0.5 per cent. are capable of neutralizing the effect of 0.1 per cent. of sulphur. Although quantitative experiments cannot be made so readily, oxygen appears to act in much the same way as arsenic, forming an eutectic alloy in which the impurities remain dissolved, and are thus rendered harmless. From these results it appears that the properties of commercial copper can be largely altered by judicious blending of impurities, and that a given sample may be defective by reason of an excess or a deficiency of foreign elements.—"The Metal Industry."

THE ABUSE OF PHOSPHORUS.

Metallurgically, phosphorus is a good servant but a bad master. We regret to say, however, that, even at this late day, the true function of phosphorus in alloys is not generally understood. By many it is considered only as an ingredient of the alloy, and is added in large amounts in the same manner that tin

or zinc is introduced. Those who do this finally wonder why their phosphor-bronze is not as satisfactory as standard brands.

The real agency of phosphorus in alloys is the reduction of the oxide of copper or tin, which is always formed when these metals are melted, and it is not intended as an ingredient of the alloy. Up to a certain amount, phosphorus is a benefit in various alloys, but beyond acts as a positive injury. This will be readily seen when one stops to consider that phosphorus is not a metal at all, but is a brittle, non-metallic substance which possesses no strength or ductility. The amount necessary in phosphor-bronze is a quantity just sufficient to reduce the oxides present, and such an amount is rarely over 0.05 per cent. The ideal alloy of this nature is one in which there has been just enough phosphorus added to deoxidize the alloy, but no more. An excess or increase over the deoxidizing amount acts prejudicially.

We occasionally see mixtures given which contain as high as 2 per cent. of phosphorus, and we only ask that these be tried in order to prove the wisdom of our remarks. Contrary to the usual belief, the amount of phosphorus should decrease rather than increase as the proportion of tin is increased. Leaving out the question of the use of scrap, it will be found that for rolling mill work—*i. e.*, plates, bars or rods cast in metal molds—that 0.05 per cent. of phosphorus is the proper amount, and under no consideration should more be added. It is often believed that an alloy can be hardened by phosphorus, and indeed it can, but the alloy will not roll. In all alloys intended for rolling the percentage of phosphorus must be kept the same, and if hardness is desired it may be obtained by increasing the tin.

For sand castings it will be advisable to use more phosphorus than that employed for rolling mill work. This is on account of the use of so much scrap, the phosphorus of which is oxidized out by repeated meltings. In order to allow for such oxidation the excess of phosphorus is introduced. Were nothing but new metal used the amount of phosphorus given before (0.05 per cent.) would be ample, and if castings of the soundest nature and highest tensile strength and ductility are desired this amount must be kept uniform. If the usual run of sand-casting work is

made and the material in the form of gates, risers, bad castings, etc., is repeatedly melted, then an amount of phosphorus equivalent to 0.25 per cent. should be introduced. In connection with the large amount of phosphorus which is often recommended in alloys for sand castings, we would say that in every case we have found that blowholes were present in the casting.

In conclusion, we desire to criticise the user of phosphor-bronze in a small way who persists in making his alloys from stick phosphorus. No more dangerous substance ever enters the brass foundry, and in addition the resulting alloy is never uniform. The phosphorus only enters the alloy in a small amount, and the balance is wasted. If absolute uniformity is desired, and with no danger, the use of phosphor-tin or phosphor-copper for introducing the phosphorus is to be recommended. The phosphorus may then be added to the alloy in absolute amounts and without the uncertainty which follows the use of stick phosphorus. In the small way in which phosphor alloys are used in some foundries, the latter practice certainly shows no economy, and is surrounded with much danger.—"The Metal Industry."

CHIMNEY GAS ANALYSIS.

* * * *

The best of plants will not prove economical if it is turned over to the tender care of an ignorant and incompetent man. The engineer too often pays little attention to what takes place in the boiler room, and the firing of the furnace is left to a man with no conception of fuel economy.

Possibly one reason for this condition, which is altogether too common, is the fact that the proper methods of controlling boiler operations are considered too scientific to be mastered by the average engineer or manager, let alone the average fireman. To the layman anything pertaining to chemical analysis seems to be shrouded in a mystery only to be unraveled by a specialist. The analysis of chimney gases is not, however, by any means beyond the ability of a careful man, particularly with apparatus

which is practically automatic in its use. With such devices the losses due to incomplete combustion may be readily calculated.

One of the first principles of combustion taught the student is that a greater quantity of air must be actually used in a furnace than is required to supply the necessary oxygen. Some writers have placed the excess at 50 per cent. for the best results, but it has been found by analysis of the gases that this figure need not always be reached. The smaller the quantity of unnecessary air the smaller the quantity of heat carried away by the chimney. One important object of anylyzing gases and determining their weight per pound of fuel is to obtain information as to the extent of this loss and ascertain what remedy, if any, may be applied to reduce surplus air. The other object in view is to ascertain the quantity of unconsumed gas, locate the cause which produces it and adopt means to prevent it. All the products of combustion which are concerned in the operation of a boiler are discharged into the chimney. If their weight be ascertained, and if the quantity of unconsumed matter be determined by analysis, these data, in connection with the temperature of the gases, furnish all the figures necessary for computing nearly the whole loss.

The importance of the subject is such as to merit more attention than is now given it. It is particularly timely to mention it again since German engineers are now paying unusual attention to the development of apparatus for rendering gas analyses matters of very simple manipulation. The Krell-Schultze apparatus, for example, takes a photographic record, if desired, of the percentage of carbon-dioxide in the gases at all times. This apparatus was tested by Professor Bunte in the boiler room of the polytechnic school at Carlsruhe, and found to give results agreeing very well with those of chemical analyses. The Magdeburg Association for Steam Boiler Operation has also endorsed this instrument. In mentioning it, there is no intention to reflect on the apparatus of Orsat, Ados, Callendar and others. It is only desired to point out that a device has already been employed for several years in Germany, which is entirely automatic in its operation and requires very little attention from the engineer in order to furnish the information that will enable the boiler

plant to be operated with practically the same degree of economy characterizing the tests for accepting such a plant.—"The Engineering Record."

THE NEW "SCOUTS."

In view of the authorization by our Congress of three scout cruisers of 3,750 tons trial displacement (about 4,000 tons full load), and in comparison with the article reprinted from "Engineering," London, page 670, of the May issue of the JOURNAL, the following editorial from the "London Times" will be of interest. The total authorized cost of our scout cruisers per vessel is $2,200,000.

The recent launch at Barrow of the *Sentinel*, the first vessel of the new "scout" class, seems to afford a suitable opportunity for considering the characteristics of this type of vessel. In his statement for 1902 Lord Selborne described the genesis of the type as follows:

When destroyers were first designed it was not contemplated that they would be frequently used otherwise than as working from a fixed base. Experience, however, has shown that vessels with greater sea-keeping power are required for service with fleets, and accordingly the Board have decided both materially to strengthen the type of future destroyers and also to create a new class altogether, to which the name "scout" has been given. It is proposed not to initiate a design for this new class at the Admiralty, but to invite the private shipbuilders of the country to give the Navy the benefit of their creative ingenuity by submitting designs to fulfil certain stated conditions.

Thus the "scout" is essentially an enlarged destroyer—very much enlarged, as will shortly be seen—and its main purpose apparently is to discharge those functions of service with fleets which destroyers have so far been called upon to discharge, but which experience has shown them to be not very well fitted to discharge, on account of their limited coal endurance and their indifferent sea-keeping power. Four years ago the need for vessels of this class was pointed out by one of our correspondents

at the naval maneuvers of 1900. Speaking of the employment of destroyers he said:

For their specific function of destroying torpedo boats they are invaluable, but that function is practically limited to narrow waters, because their very limited coal supply at high speeds quite unfits them for ocean cruising, and even for effective action at any distance from their base. But for this they would be invaluable as fleet messengers or "naval gallopers," as they might be called, and it may be worth considering whether vessels of the destroyer type with a somewhat larger displacement mainly devoted to coal stowage, with no torpedo equipment and an armament only adapted for defence against destroyers proper—since they could show a clean pair of heels to any other class of vessel—and propelled by turbine engines, might not serve a very useful purpose as naval gallopers. The temptation to employ destroyers for this purpose is very strong; but if yielded to it withdraws destroyers from their proper function and does not furnish an efficient galloper—the essential requirement of which is high speed combined with as large a coal supply and as high a degree of seaworthiness as is compatible with a limited displacement.

It is apparently on these lines that the "scouts" have been evolved, though, as we shall presently see, it is far from clear that their efficiency for the purposes indicated will be commensurate with their very high cost. The conditions imposed on their designers were, as given in the appendix to Lord Selborne's Statement for 1903, that they should maintain a speed of 25 knots for eight hours' continuous steaming when in ordinary sea-going condition, and that the coal supply should be sufficient for a radius of action of not less than 3,000 nautical miles at 10 knots' speed. Eight are now under construction by four different contractors. The following details are taken from the Navy Estimates for 1904–5.

It will be seen that the dimensions of the various designs do not greatly differ, and that their common characteristics are a very large I.H.P., a high speed for vessels of their displacement, a very light armament, and a very limited coal capacity at

Name.	By whom designed.	When and where laid down.	Length.	Breadth.	Mean load draught.	Displacement at load draught.	Makers of machinery.	Estimated I.H.P. on contractors' trial, forced draught.	Corresponding estimated speed at load draught, smooth water, clean bottoms.	Coal capacity at load draught.	Armament, not including machine guns or torpedoes.
											Ten 12pdr. and eight 3 pdr. q. f. guns.
Adventure... *Attentive*...	Armstrong, Whitworth and Co.	Jan. 7, 1904 Jan. 8, 1904 *	*ft.* 374	*ft. in.* 38–3	*ft. in.* 13–3	*tons.* 2,850	Hawthorn, Leslie and Co.	16,000	*knots.* 25	*tons.* 150	
Sentinel.... *Skirmisher*	Vickers, Sons and Maxim.	June 8, 1903 July 29, 1903 Barrow.	360	40	14–2	2,900	Vickers, Sons and Maxim.	17,000	25	150	
Forward.... *Foresight*...	Fairfield Shipbdg. and Eng. Co.	Oct. 22, 1903 Oct. 24, 1903 Glasgow.	365	39–2	14–1	2,800	Fairfield Shipbuilding and Eng. Co.	16,500	25	150	
Pathfinder.. *Patrol*.....	Cammell, Laird and Co.	Aug. 15, 1903 Oct. 31, 1903 Birkenhead.	370	38–9	13–9	2,850	Cammell, Laird and Co.	16,500	25	150	

* Newcastle-on-Tyne.

load draught. Their cost is also very high indeed. The *Adventure* is to cost £268,645, the *Sentinel* £276,384, the *Forward* £281,944, and the *Pathfinder* £272,907—an average of over £275,000 ($1,336,500) apiece. It may be assumed, no doubt that the figure given in the Navy Estimates for "coal capacity at load draught" is considerably less than the full bunker capacity of the ships. It may well be that they will be able to stow twice as much, or more, let us say 350 tons, in their bunkers, but the additional 200 tons will, of course, increase their displacement and draught, and thereby in some measure diminish their speed. The condition imposed by the Admiralty is that the ships should maintain a speed of 25 knots for eight hours' continuous steaming when in sea-going condition. For this purpose it is safe to estimate that the consumption of coal would be not less than 2½ pounds per I.H.P. per hour, so that with an I.H.P. of 16,500 the ships would consume rather more than 18 tons per hour, or rather more than 144 tons in the prescribed eight hours' hard steaming at full speed. If they started at load draught they would thus have less than six tons of coal left in their bunkers. In point of fact, they would probably have none at all, because it is well known that every warship consumes no inconsiderable fraction of her total coal supply for purposes other than steaming; for steering, for lighting, for condensing, and for ventilating. She must have fresh water for her boilers, she must have an adequate draft in her stokehold, and her working efficieny is certain to be in some measure impaired if the service of electric lights is suspended in the darker parts of the ship.

If, on the other hand, they started with bunkers full up to 350 tons, they would probably steam at first somewhat more slowly, while consuming coal at the same rate. But for the sake of argument we will assume that in all cases they are capable of steaming at 25 knots for eight hours, covering in this time 200 miles. Afterwards their speed would tend to fall considerably, though, still having over 200 tons of coal in their bunkers, they could steam perhaps for some 500 miles further at a reduced speed of 20 knots or thereabouts. Or, again, if they started with bunkers full at a speed of 20 knots they would probably consume about

200 tons of coal a day, so that on these terms they could cover about 840 miles in forty-two hours with 350 tons of coal. Having regard to the inevitable consumption of coal in warships for purposes other than steaming, we may assume that on these terms the "scouts" could steam at 20 knots from Gibraltar to Toulon, a distance of some 700 miles, or from Malta to Toulon, a distance of some 600 miles; but they would have no coal to bring them back again, nor could they in any case steam at 20 knots from Plymouth to Gibraltar or from Gibraltar to Malta. It is true that at lower speeds their radius of action would be much more extended. Indeed, the requirement that they should be able to cover 3,000 miles at 10 knots would enable them to steam from Plymouth to Alexandria without coaling. But, except for the purpose of making a passage, this seems to be no special advantage. The Navy does not require a special and very costly type of ship to steam 3,000 miles at 10 knots. There are plenty of ships in the service that are capable of that not very remarkable achievement. Even a destroyer can make a passage of very respectable length at 10 knots.

The question thus arises, What particular function in the strategic and tactical economy of the Navy are the "scouts" intended to discharge? Obviously they have no fighting value, except against torpedo craft. Nor are they adapted for oceanic warfare of any kind. As they cannot fight, they must scout, and unless they scout at full speed they are no better, even as scouts, than any other modern cruiser of high speed, while in every other respect they are manifestly and hopelessly inferior. On the other hand, if they are to scout at full speed, their full power would be exhausted in eight hours, and it seems hardly likely that an admiral in blue water would care to hamper himself with vessels which cannot do their special work for more than eight hours, and can defend themselves only by running away, even from a third-class cruiser of the *Pelorus* type. In calling these vessels "scouts" it seems to us that the name is singularly misapplied. They are, no doubt, somewhat better fitted to serve as "gallopers" than destroyers are, because they will probably keep their speed in a heavy sea better than destroyers can. But

their range is so limited that they will not, after all, be very efficient as gallopers. They will not be much less dependent on a base than destroyers are, and, though they may serve many a useful purpose in narrow waters like the Channel or the Irish Sea, it seems almost certain that they will be useless for blue-water work.

There is, however, perhaps, one operation of warfare in which their very limited range might not be found seriously to hamper their efficiency as gallopers, and that is in the case of a blockade. The development of torpedo craft, including the submarine variety, has manifestly made it impossible to carry on a naval blockade in the fashion instituted by St. Vincent and perfected by Nelson and Cornwallis. The battleships and heavy cruisers destined to engage the enemy's fleet, should it attempt to leave its port, must henceforth be stationed at a position so far distant from the blockaded port as not to be readily accessible to torpedo craft issuing therefrom—say at a distance of not less than 100 miles, either at a flying base seized for the purpose, as Admiral Togo has established a base in the Korean Gulf, or, if necessary, in the open.

In this disposition it is obviously necessary to secure rapid communication between the torpedo craft and other suitable vessels keeping a close watch on the blockaded port and the main fleet stationed 100 miles or more away, and, if not at a flying base, then probably constantly shifting its position. For this purpose a few gallopers, able to protect themselves against torpedo craft and to steam at 25 knots, might well be found very useful. They could reach the main fleet in four hours, and could probably communicate with it in less than three if wireless telegraphy were used, and the function thus discharged by them would be well within the limits of their coal endurance, more especially if the main fleet were stationed at a flying base where coal could be readily obtained and shipped. But it still remains to be seen whether the "scouts" will have for this purpose such an advantage over destroyers as is commensurate with their enormously greater cost. They are practically no more effective against torpedo craft than destroyers are, they are totally defenseless

against any larger type of vessel, and apparently their only superiority over the destroyer is that they can probably maintain a speed of 25 knots in a rough sea, whereas the destroyer can maintain the same speed only in a smooth sea, the radius of action of the destroyer in smooth water not being appreciably less than that of the "scout" in a sea way.

As the new and stouter, but slower, destroyers now being built are, according to Lord Selborne, to have "greater sea-keeping power for service with fleets," and as the experience of the present war has shown that destroyers even of the lighter and faster type are capable of sustained and very effective war-service in a very stormy sea, the advantage of the "scout" over the destroyer becomes more problematical than ever. Yet the eight scouts will cost £2,200,000. If we put the cost of a destroyer at £75,000, the country could have nearly thirty destroyers for the same money.

Indeed, this question of cost seems to us to be so important as almost to decide the matter. The table given on page 992 is significant, and none the less significant the more it is analyzed.

If any one analyzing this table were to come to the conclusion that the new "scout" is one of the most costly and least efficient warships ever built, it might be hard to gainsay him. The figures, at any rate, seem to point in that direction, and though we cannot but suppose that the policy of the Admiralty in building these vessels has more to be said for it than we have been able to discover, yet it certainly seems time that that policy should be more fully explained to Parliament and the country. The truth seems to be that the scouting functions proper of a fleet engaged in a blue-water campaign cannot be discharged by vessels of small displacement. Even the *Bacchante*, with a displacement of 12,000 tons and a coal capacity of 1,600 tons, had reached the end of her tether in the maneuvers of last year, when the fleet to which she was attached had steamed about 1,000 miles from its base. It is not necessary to employ an armoured cruiser for purely scouting purposes, if the vessel so employed has the heels of her possible enemies.

But it is necessary that the vessel so employed should have a

Name and class.	Cost.	Displacement.	I.H.P.	Speed (knots).	Coal.	Armament of 2d and 3d class cruisers compared with "scout."
	£	*tons.*			*tons.*	
London, 1st class battleship.....	1,114,808	15,000	15,000	18	900 / 2,000	
Drake, 1st class armored cruiser....	1,050,675	14,100	30,557	23	1,250 / 2,500	
Kent, 1st class armored cruiser ...	735,011	9,800	22,249	22.5	800 / 1,600	
Talbot, 2d class cruiser, sheathed	280,119	5,600	9,600	20	550	11 6-in. q. f., 9 12-pdr., 1 3-pdr.
Amethyst, 3d class cruiser.....	228,527	3,000	9,800	21.75	300	12 4-in. q. f., 8 3-pdr.
Pioneer, 3d class cruiser.	154,480	2,200	7,000	20	250	8 4-in. q. f., 8 3-pdr.
Violet, t. b. d.....	75,000 approx.	283	5,400	30	80	
Itchen, t. b. d.....	75,000 approx.	550	7,000	25.5	130	
Sentinel, scout	276,384	2,900	17,000	25	150 / 350	10 12-pdr., 8 3-pdr. q. f.

very large coal capacity, even if she has very little else. The new Cunarders would for this reason make almost incomparable scouts in a blue-water campaign, and they would need no heavier armament than such as would suffice to keep off torpedo craft. It is true that the new Cunarders are to be very costly vessels. But if we want blue-water scouts—as no doubt we do—we must be content to pay the price for them. It is not easy to see the use of building so-called "scouts" which are not blue-water scouts at all, and which, even in narrow waters, will probably be found to be nothing more than very large, very costly and not very fast destroyers. For the cost of the eight "scouts" we might have had approximately two *Londons*, or two *Drakes*, or three *Kents*,

or eight up-to-date *Talbots*, or ten *Amethysts*, or fourteen *Pioneers*, or thirty destroyers of the *Violet* or *Itchen* types. Is it certain that we have laid out our money to the best advantage? Would it not at least have been wiser to build one or two "scouts" as experimental vessels, and to await the result of the experiment before embarking on so large and questionable an expenditure?

SHIPS.

UNITED STATES.

Names of New Vessels.—The following names have been assigned to the vessels authorized by the Act making appropriations for the Naval Service, approved April 27, 1904:

Battleship *No. 25*, - - -	*New Hampshire.*
Armored Cruiser *No. 12*, - -	*North Carolina.*
Armored Cruiser *No. 13*, - -	*Montana.*
Scout Cruiser *No. 1*, - - -	*Chester.*
Scout Cruiser *No. 2*, - - -	*Birmingham.*
Scout Cruiser *No. 3*, - - -	*Salem.*
Fleet Collier *No. 1*, - - -	*Erie.*
Fleet Collier *No. 2*, - - -	*Ontario.*

Ohio.—Speed Trials of.—The battleship *Ohio*, built by the Union Iron Works, of San Francisco, ran her speed trials at Santa Barbara, California, July 30th. Her actual speed was 17.816 knots, .184 below the requirement of 18 knots.

The *Ohio* is one of the three battleships of the *Maine* class, authorized May 4, 1898. Although the first to be launched, she fell behind her sister ships the *Maine* and the *Missouri*, which are now in commission.

The principal dimensions of the *Ohio* are: Length, 388 feet; beam, 72 feet 3 inches; draught, 23 feet 6 inches; displacement, fully equipped for service and carrying normal supply of 1,000 tons of coal, 12,500 tons; full load displacement, 13,941 tons. The actual normal displacement of the *Maine* is 12,300 tons, and of the *Missouri* 12,240 tons. The *Ohio* and the *Missouri* are equipped with Thornycroft boilers, while the *Maine* is fitted with Niclausse boilers. Main armament of the *Ohio*, four 12-inch guns, sixteen 6-inch guns, two submerged torpedo tubes.

Detailed data of these trials will be given in a later issue.

South Dakota.—LAUNCH OF.—The armored cruiser *South Dakota* was launched from the yard of The Union Iron Works, San Francisco, on Thursday, July 21, her sister ship the *California*, having been launched from this yard on April 28. The two vessels are practically identical, and reference may be made to the May JOURNAL, page 678, for particulars.

The general dimensions of the *South Dakota* are: Length at water line, 502 feet; breadth, 69 feet 6½ inches; draugth, 24 feet 1 inch; displacement, 13,800 tons; coal capacity of bunkers, 2,000 tons; speed, 22 knots; I.H.P. 23,000.

Blakely.—The torpedo boat *Blakely*, built by the George F. Lawley & Son Corporation, Boston, ran her official speed trials on July 22. While data of her performance are not yet available for publication, it is stated that her speed for the one-hour's endurance run was 24.5 knots, .5 in excess of contract requirements, and that a speed of 25.7 knots was made during the speed and standardization runs, 25 knots being required.

The *Blakely* is a sister vessel to the *DeLong*, built by the same firm, the trials of which were described in the JOURNAL, page 825, Vol. XIV, No. 3, August, 1902. The *Blakely's* trials have been delayed to this late date due to defects which developed in the cylinder castings of one of the main engines on earlier trials.

Detailed data of her successful trials will be given in a later issue.

Dubuque.—LAUNCHING OF.—Gunboat No. 17, *Dubuque*, was successfully launched August 15th, from the works of her builders, the Charles L. Seabury and Gas Engine and Power Company, Consolidated, Morris Heights, New York.

The *Dubuque* and *Paducah*, building by the same firm, are small gunboats, having the following chief characteristics:

Length between perpendiculars, 174 feet; length over all, 198 feet 7 inches; breadth, extreme, outside of planking, 35 feet; trial displacement, 1,085 tons; trial draught, 12 feet 3 inches; designed speed, 12 knots.

There will be two vertical triple-expansion engines, designed to develop 1,000 I.H.P., at about 225 revolutions per minute. The boilers, two in number, are of the Babcock & Wilcox

type, having a total grate surface of 100 square feet and total heating surface of 4,200 square feet, designed for 265 pounds pressure.

Maryland.—DOCK TRIALS.—The contractors have carried out dock trials of this armored cruiser in preparation for their preliminary speed trials which will be undertaken at an early date.

Colorado.—DOCK AND PRELIMINARY TRIALS.—Successful dock trials were made and a preliminary speed trial has been run which is said to have been satisfactory, though reliable data is not at hand for publication. It is believed, however, that the contract speed of 22 knots can be reached without great difficulty though the power developed will doubtless be in excess of the 23,000 I.H.P. designed.

Louisiana.—LAUNCH OF.—The battleship *Louisiana* was launched from the yard of the Newport News Ship Building & Dry Dock Co., Newport News, Va., on August 27th. The sister ship *Connecticut*, building at the New York Navy Yard, is to be launched on September 29, so that the *Louisiana* is a month ahead of the *Connecticut* in date of launching. The *Louisiana* is 54 per cent. completed, while the percentage of completion of the *Connecticut* is slightly less.

The dimensions of the *Louisiana* are as follows: Length on load-water line, 450 feet; beam, extreme, to outside of plating, 76 feet 8 inches; draught, on normal displacement of 16,000 tons, 24 feet 6 inches; speed, 18 knots; complement of officers, 41; crew, 778. There are two sets of vertical, inverted, triple-expansion, direct-acting engines, designed for 16,500 collective horsepower at 120 revolutions per minute. Each engine is placed in a separate watertight compartment, the cylinders being 32½ inches, 53 inches and two 61 inches in diameter, by 48 inches stroke of piston. Steam at 265 pounds pressure is supplied from twelve boilers of the Babcock & Wilcox type, placed in six watertight compartments. The total grate surface of the twelve boilers is 1,097 square feet, and the total heating surface 52,752 square feet. The smoke pipes are three in number, in line fore and aft.

There will be a complete water-line belt 9 feet 3 inches wide amidships and stepped down at the ends. In wake of machinery

spaces the armor will be 11 inches thick at the top, tapering to 9 inches at the bottom. Forward and aft the armor will step down to 9 inches at the top and 7 inches at the bottom, then to 7 inches at the top and 5 inches at the bottom, then to 5 inches constant thickness, then to 4 inches constant thickness. There will be lower casemate armor 6 inches thick and upper casemate armor 7 inches thick. The 12-inch turret armor will be 12 inches thick on the port plates, 8 inches on the sides and back; the 8-inch turret armor will be 6½ inches thick on the port plates and 6 inches on the sides and back.

The main battery will consist of four 12-inch breechloading guns, mounted in two turrets, one forward and one aft; eight 8-inch breechloading guns mounted in four side turrets; and twelve 7-inch breechloading guns, R.F., in casemates on the main deck. There will be a secondary battery of twenty 3-inch (14-pounder) R.F. guns, 50 calibers in length; twelve 3-pounder semi-automatic guns; six 1-pounder automatic guns; two 1-pounder semi-automatic guns; two 3-inch field pieces, two machine guns of .30 caliber and six automatic guns of .30 caliber. There will also be four 21-inch submerged torpedo tubes.

AUSTRO-HUNGARY.

The Austro-Hungarian Torpedo-Boat Flotilla.—The Austro-Hungarian Government has determined to completely reorganize their torpedo-boat flotilla, and has entrusted the designs of the vessels to Yarrow & Co., of Poplar. Two types of vessels are to be constructed—destroyers and first-class torpedo boats. The former will be somewhat smaller than those recently added to the British Navy; they will have a speed of 28 knots carrying 100 tons. The first-class torpedo boats are to have a speed of 25¾ knots carrying 55 tons. The destroyers will have twin screws and the torpedo boats single screws. The latter will have one set of machinery of identically the same design as that in the destroyers, which will have two sets, and all parts of the engines for both classes of vessels will be interchangeable, so that in time of war repairs can be executed with the greatest promptitude on account of the simplification of the duplicate

parts most liable to damage. This determination to carry out in their torpedo-boat flotilla interchangeability to the fullest extent shows a very far-sighted policy on the part of the Austro-Hungarian Government. Yarrow & Co. have been entrusted with the contract for one vessel of each type, to be constructed at their works; the remaining vessels will be built in the Austrian shipyards from the same designs.

ENGLAND.

New Battleships, Nelson Class.—Tenders for the new battleships of the *Nelson* class will be invited towards the end of August. The chief characteristic will be the great gun power. The design is to ensure a high gun platform, and in the new *Nelson* class there will be no guns on the main deck as in earlier ships. All of them will be on the upper deck, which will give them a more distant horizon. The guns will be more powerful. There will be two barbettes—one forward and the other aft, and in each there will be two 12-inch breechloaders. The secondary armament will consist entirely of 9.2-inch guns. In the *King Edward VII* class there are four of these guns, in addition to ten 6-inch quick firers, but in earlier ships there were twelve or fourteen 6-inch guns only. There will be in the *Nelson* class ten 9.2-inch guns, which will make them by far the most powerful ships afloat. Twin 9.2-inch guns will be mounted in turrets at the four quarters of the citadel, and a single gun in the center on each side. These guns will be built into the upper deck, which is to be heavily armored, the mechanism and mounting being protected by armored hoods or turrets. Thus the broadside of 9-inch Krupp armor will be utilized for protection from broadside attack, and the main armored bulkheads forward and aft for shielding the gun mountings from raking fire. The broadside armor will not be weakened by openings, and the lower parts of the gun mountings and ammunition hoists will be effectively protected. The displacement will be about 15,000 tons and the speed about 19 knots.

Commonwealth.—STEAM TRIALS OF.—The *Commonwealth*, the first battleship of the *King Edward VII* class to proceed on

trials, has completed with most satisfactory results the steam tests specified in the contract. This vessel was ordered from the Fairfield Shipbuilding and Engineering Company, Govan, in 1902, and the first keel plate was laid on June 17 of that year; she was launched on May 13, 1903, and her contract steam trials were completed on June 25; so that, although she has yet to be fitted with ordnance, her completion at the Fairfield Works will be well within two-and-a-half years. The vessel is 425 feet long between perpendiculars, and 453 feet 9 inches over all; 78 feet beam, and, when drawing 26 feet 9 inches of water, displaces 16,350 tons. She is clad for the greater part of her length with a water-line belt 9 inches thick, tapering to two inches at the ram, and excels all preceding British ships in the power of her artillery, having four 12-inch guns mounted in pairs in barbettes, four 9.2 inch guns mounted singly in barbettes at the four quarters of the citadel, and ten 6-inch quick-firers on central-pivot mountings in a concentrated casement between decks, as in the Japanese ship *Mikasa*, with 7-inch armor in front, while the broadside between this and the water-line belt has an 8-inch strake. Thus the whole broadside above water in the central part of the ship is armored.

The machinery consists of two sets of four-cylinder triple-expansion engines, having cylinders 33½ inches, 54½ inches, 63 inches and 63 inches in diameter respectively, with a piston stroke of 48 inches. Steam at 270 pounds is supplied from sixteen Babcok and Wilcox water-tube boilers, having about 47,250 square feet of heating surface and 1,400 square feet of grate area. The engines working at 120 revolutions were to develop 18,000 indicated horsepower to give the ship a speed of 18½ knots. On trial these results were considerably exceeded.

The vessel had first been placed in the dry dock of the Clyde Trust, and in connection with this it should be mentioned that, with the *Commonwealth*, of 453 feet 9 inches and 16,350 tons displacement, there was docked a second-class cruiser—the *Hyacinth*—of 350 feet and 5,600 tons, which had been undergoing an overhaul at the Fairfield Works.

A preliminary steam trial of the *Commonwealth* was made June 20th, prior to the ship being taken over by the Admiralty

officers. On the 21st, a start was made with the official steam-trials, consisting of thirty hours' steaming, each at one-fifth power and seven-tenths power, and a final trial of eight hours at full power. The first trial was finished at 5 P. M. on the 22d, and at 8 P. M. on the same day the vessel was again under way for the seven-tenths-power trial, which was completed early on the 24th. For the full-power trial of eight hours a start was made at 3 A. M. on the 25th, and on completion of the steaming trial, and when the vessel was well out in the Firth of Clyde, the tests of starting and stopping the machinery, also the steering and turning tests, were made. All the trials were carried out to the entire satisfaction of the officials representing the Admiralty, and a return to the anchorage was made about 7 o'clock on the 25th.

Before proceeding on each of the trials the vessel was ballasted so as to float about 2 inches deeper than her nominal load draught, and the following are the official steam-trial results:—

	I.H.P.	Mean revolutions.	Mean speed, knots.	Coal consumption per I.H.P. per hour, pounds.
One-fifth power.....	3,644	70.65	11	1.74
Seven-tenths power.....	12,769	107.45	17.9	1.68
Full power.....	18,538	120.05	19.01	1.83

The speeds at the higher powers were recorded as the result of six runs over the measured mile at Skelmorlie. The results on the first series at 70 per cent. of the total power were as follows:

RESULT OF SIX RUNS ON MEASURED MILE AT 75 PER CENT. OF FULL POWER.

No. of run.	Time on mile.	Speed in knots.	Revolutions per minute. Mean of P. and S.	I.H.P., collective.
	min. *sec.*			
1	3 28	17.3076	107.6	12,735
2	3 16	18.3673	108.4	12,772
3	3 16.4	17.4418	109	12,931
4	3 15.6	18.4049	107.4	12,417
5	3 26.7	17.3410	107.6	12,519
6	3 14.4	18.5185	108.9	12,892

The details of the runs at full power, June 25th, are also given:

RESULT OF SIX RUNS ON THE MEASURED MILE AT FULL POWER.

No. of run.	Time on mile.	Speed in knots.	Revolutions per minute. Mean of P. and S.	I.H.P., collective.
	min. *sec.*			
1	3 8.4	19.1082	120.35	18,478
2	3 8.2	19.1285	119.1	17,931
3	3 12.8	18.6721	119.5	18,213
4	3 6.5	19.3029	120.15	17,947
5	3 11.1	18.8382	119.3	17,987
6	3 4.1	19.5546	119.4	18,205

It will be noted that the trials of the *Commonwealth* only occupied five days. The vessel returned to Fairfield Dock June 27th, where she will receive her heavy armament and be finished complete for the Fleet Reserve.

Duke of Edinburgh.—LAUNCH OF.—The first-class armored cruiser *Duke of Edinburgh*, which was launched at Pembroke Dock on June 14th, is the first of the new class of armored cruisers to take the water, the remaining five being the *Black Prince*, *Achilles*, *Natal*, *Warrior* and *Cochrane*. These cruisers represent a type which has been evolved as the result of experience gained with a succession of armored cruisers, commencing with the *Drake* and *Cressy* classes, and passing on to the *Monmouth* and the improved *Monmouth* or *Devonshire* type. The weakness of all the vessels named consisted chiefly in the adoption of the 6-inch B.L. gun as the preponderating arm. In the *Duke of Edinburgh* the 6-inch gun is retained on the main deck, but her design provides for six 9.2-inch guns to be mounted in barbettes on the upper deck—one forward, one aft and two on each broadside. This powerful armament, and the fact that these vessels will be the first cruisers to have a complete armor water-line belt, are the most important distinctive feature of the *Duke of Edinburgh* and her sisters. The remaining armament will comprise twenty-four 3-pounder Q.F. guns, with four machine guns. The full armament of the ships will therefore be six 9.2 B.L., ten 6-inch B.L. and twenty-eight smaller guns. This repre-

sents an enormous increase in offensive power over that possessed by any previous cruiser. In this connection, also, she is possessed of a new feature in the shape of a center-line submerged torpedo tube. Years ago it was customary to fit stern tubes above water, but they were abandoned because of difficulties experienced in directing the torpedoes. Latterly, however, a new invention has removed that difficulty, and hence the *Duke of Edinburgh* is to be fitted with a stern submerged tube. She will also have one submerged tube on each side near the bow. All three will discharge 18-inch torpedoes.

It is reported that in the four last laid down vessels of this class, the *Achilles*, *Natal*, *Cochrane* and *Warrior*, the ten 6-inch guns on the main deck are to be done away with, and four additional 9.2-inch will take their place on the upper deck, but this seems doubtful.

The principal dimensions of the *Duke of Edinburgh* are: Length, 480 feet; extreme beam, 73 feet 6 inches; mean draught as designed, 27 feet (her actual draught when complete will probably be about 9 inches more); displacement, 13,550 tons. The estimated weight of the hull when complete is 8,015 tons. There is a complete armor water-line belt 6 inches thick amidships, tapering to 4 inches forward and 3 inches aft; the 3-inch and 4-inch armor extends only from the lower to the main deck, but the 6-inch will be carried to the upper deck, and superimposed on the main deck at the points forward and aft where the 6-inch armor terminates. Athwartships, armor bulkheads 6 inches thick will be fitted between the main and upper decks, which, with the side armor, will form a central citadel. The lower deck of the ship is curved downwards towards the sides, forming an arch throughout. It is built of two thicknesses of $\frac{3}{8}$-inch plating. The main deck within the citadel is formed of a single thickness, but outside it at both ends it is worked in two thicknesses of $\frac{1}{2}$-inch plating for protective purposes. The upper deck over the citadel is built of two thicknesses of $\frac{5}{8}$-inch plate, but beyond it towards both ends it is worked in single thickness. The plating of the top sides, where there is no armor, and aft, is $\frac{7}{16}$-inch thick.

Above the upper deck, terminating at about the same point as the thick side armor, a superstructure will be erected, which will be carried forward to form a boat deck. A similar superstructure will be erected above the forecastle, also at about the point where the thick side armor terminates forward. Twenty of the 3-pounder guns will be mounted on these superstructures, ten forward and ten aft. Along the sides, but at some distance from them, hammock berthings will be built, thus connecting the aftermost superstructure with the forecastle. On the upper deck abaft the superstructure, and on the forecastle immediately before it, will be constructed the barbettes for two of the 9.2-inch guns, of 6-inch armor, built on a strong substructure, erected from the lower deck, in each of which one 9.2 gun will be mounted. These guns will have an arc of fire of 270 degrees. At the four corners of the central citadel on the upper deck similar barbettes will be constructed, and in these the other 9.2-inch guns will be mounted. The aftermost of these guns on both sides will fire 2 degrees across a fore-and-aft line, and in order to permit of this, the top-side plating above the main deck has been recessed back to form a lengthy embrasure. Beneath these corner 9.2-inch guns 6-inch guns will be mounted on the main deck, and the two after ones will have a similar range to the larger guns above them. Between the foremost and aftermost 6-inch guns, at equal distances along both sides, three other 6-inch guns will be mounted, all at ports, and all having a range of 120 degrees.

The interior of the ship is divided into compartments on much the same lines as other ships. The boiler and engine rooms occupy the middle part below the lower deck, and the magazines, shell rooms, and store rooms are at the extremities. The lower coal bunkers skirt the boiler rooms along the sides, and the ammunition passages, which afford communication with the principal magazines and shell rooms; the tubes through which the ammunition is passed to the fighting positions occupy the inner upper corner of the coal bunkers on both sides. These passages contain a novel feature; immediately under each of the broadside guns, magazines and shell rooms to contain ammunition for

"ready use" are to be constructed. These compartments will considerably reduce the coal capacity of the bunkers, but this point is apparently considered of comparatively little importance, as the inner-bottom spaces on both sides throughout the entire length of the boiler rooms and below the second longitudinal have been constructed to carry oil fuel. The coal capacity of the ship is estimated at 1,000 tons.

On the main deck aft, the officers' cabins and the wardroom will be situated; in the middle part, the central citadel, the 6-inch gun positions will be separated by 2-inch splinter bulkheads, and forward, a portion of the crew will be accommodated, the remainder being located on the upper deck in the forecastle.

The ship will have two masts and four funnels. She will be lighted throughout with electricity, and ventilated by electrically driven fans, distributing air through a system of pipes.

The propelling engines, which have been manufactured by Hawthorn, Leslie & Co., Newcastle-on-Tyne, will consist of two independent sets of vertical triple-expansion engines, each having four cylinders, of which the diameters will be: High pressure, 43½ inches; intermediate pressure, 69 inches; and low pressure (two), 77 inches. The engines will have 3 feet 6 inches stroke, and will make approximately 135 revolutions to the minute. Their united H.P. will be 23,500, and the estimated speed of the ship is 22.33 knots. In addition to the main engines, the contractors are supplying two complete sets of evaporating and distilling machinery; four engines and pumps for circulating water through the main condensers, four in number; two steering engines; four main and four auxiliary feed pumps; a complete electric installation, consisting of engines and dynamos, probably six in number; two sets of air-compressing machinery, electrically driven; and one electrically-driven ice machine.

The boiler installation will comprise twenty Babcock and Wilcox water-tube and six cylindrical boilers, the latter being 13 feet 6 inches in diameter, and 10 feet 6 inches long. Both sets of boilers will work at a pressure of 210 pounds to the square inch.

The estimated cost of the *Duke of Edinburgh* is £1,131,882. —"J. R. U. S. I."

Welland.—The new torpedo-boat destroyer *Welland* is the last of four vessels of this class built by Yarrow and Co., Poplar, to the order of the British Admiralty, the other three vessels being named *Ribble*, *Teviot* and *Usk*. There is a great change in this type of vessel from the previous class of 30-knot boats. A forecastle deck has taken the place of the turtle deck, with a galley house immediately abaft; above the galley is built the chart house, and above this again is the steering bridge and searchlight platform. The crew's quarters are under the forecastle, as well as under the main deck, so that these latter spaces are not nearly so crowded as formerly; they are also well ventilated by electric fans. In the officers' quarters there has also been a great improvement, the commander, engineer-lieutenant, sub-lieutenant and gunner, all having separate cabins, supernumeraries only having to sleep in the ward room. The armament is the same as for the 30-knot destroyers, viz: one 12-pounder quick-firing gun in the conning tower, and five 6-pounder quick-firing guns and two 18-inch torpedo tubes on the main deck. In order to obtain a stronger vessel, and one better able to accompany a fleet, the Admiralty decided upon a reduction in speed to 25½ knots on trial; but this was to be obtained with the load increased from 40 to 125 tons, together with certain weight penalties and premiums for coal consumption, at full power. As the displacement with 125 tons load exceeded 600 tons, it will be seen that it was no easy task to obtain the speed.

The boats measure 225 feet long by 23½ feet beam, and the machinery consists of two sets of four-cylinder triple-expansion engines, balanced on the Yarrow, Schlick and Tweedy system, and designed for 7,500 I.H.P., at a speed not exceeding 350 revolutions. The boilers are of the Yarrow straight-tube type, having 16,000 square feet of heating surface, and are designed for a working pressure of 250 pounds per square inch. They are placed in three stokeholds, viz: two in the middle stokehold, one each in the forward and aft stokeholds. There is one feed engine for each boiler, and one auxiliary feed engine, also two forced-draft fans and engines in each stokehold. The speed trials were carried out on the new mile at St. Margaret's

near Dover, and in the English Channel, or North Sea. The water on the Maplin mile, where Messrs. Yarrow have previously run their trials, was far too shallow for these trials, and even the St. Margaret's mile result would be doubtless improved upon if a still deeper mile could be arranged, as, for instance, in the 30-fathom water near the East Goodwin lightship.

The trials of the first two boats, *Usk* and *Teviot*, were run in December, last year; those of the *Ribble* and *Welland* were run in May. The results of the four-hours' speed and consumption trials are given on the next page.

For the first two boats, the *Usk* and *Teviot*, the coal was put into bags for convenience of handling; but owing to the very exceptional economical results obtained per I.H.P., viz: 1.77 pounds, and 2.06 pounds in the *Usk* and *Teviot* respectively, the Admiralty decided that for the future no bags were to be used, thinking that possibly, as this did not represent the exact working condition of the boat, some advantage might have been gained by this system of stowage. In the last two boats, the *Ribble* and *Welland*, the coals were stowed loose in the bunkers, and the coal consumption, which was so good in the two previous boats, came out better, being in the *Welland* 1.65 pounds of coal per H.P., and in the *Ribble* 1.57 pounds of coal per H.P.

The full-speed trials in each case followed a few days after the above, with the following results, and in the order given in the table below:

Name.	Displacement at beginning of trials.	Speed on miles.	I.H.P. on miles.	Speed—three hours.	I.H.P. three hours.	Air-pressure in stokeholds.
	tons.	*knots.*		*knots.*		*inches.*
Usk	581	25.873	7,616	26.072	7,633	1.6
Teviot	588	25.435	7,405	25.853	7,510	2
Welland...	574	26.016	7,754	26.244	7,766	1.8
Ribble.....	571	25.820	7,696	25.817	7,430	1.6

The difference in displacement as compared with consumption trial is due to the coal premium each boat had earned as mentioned above.

A slow-speed consumption trial was also run by three of the vessels, with the following results:

Name.	Displacement.	Speed for 12 hours.	Coal per I.H.P., pounds.	Notes.
	tons.	*knots.*		
Usk.....	595	12.764	1.29	Using 1 boiler and 1 engine.
Welland...	578	13.035	1.47	Using 1 boiler and 2 engines.
Ribble.....	590	13.091	1.41	Using 2 boilers and 2 engines.

OFFICIAL TRIALS OF H. M. TORPEDO-BOAT DESTROYERS.

Name.	Nature of trial.	Displacement, tons.	Speed on miles.	Speed—3 hours.	Mean indicated horsepower.	Coal per indicated horsepower per hour, pounds.	Air-pres. in stoke-holds, inches.
Teviot...	Full-power consumption..	595	25.191	25.405	7,845	2.06	2.1
	Full-power speed trial....	579	25.435	25.853	7,484	...	2.07
Usk.....	Full-power consumption..	609	25.111	25.372	7,835	1.77	1.6
	Full-power speed trial....	581	25.873	26.072	7,629	...	1.6
Ribble...	Full-power consumption..	607	25.485	25.328	7,659	1.572	1.4
	Full-power speed trial....	571	25.820	25.817	7,496	...	1.7
	12-hours 13-knot coal consumption.....	590	...	...	689	1.41	...
Welland	Full-power consumption..	604.5	25.486	25.349	7,759	1.65	1.6
	Full-power speed trial....	574	26.016	26.244	7,763	...	1.8
	12-hours 13-knot coal consumption.....	578	...	...	689	1.47	...

The trials were run in the above order, and show a steady improvement in the coal consumption.

Pathfinder.—LAUNCHING OF.—The first of the two "scouts" now building by Cammell, Laird & Co. was launched July 16th at the shipbuilding works of the company at Birkenhead. The "scouts," of which this vessel is one, are designed to be the fastest sea-going vessels in the world, and it is expected that 25 knots will be obtained on a prolonged full-power trial. The following are the principal dimensions of the vessel: Length, 370 feet; beam, 38 feet 6 inches. She will be propelled by two sets of four-cylinder triple-expansion engines of 16,500 horsepower,

balanced on the Yarrow, Schlick and Tweedy system, steam being supplied by twelve water-tube boilers of the Laird type, arranged in three watertight compartments. A protective deck is worked throughout the ship. The engines are protected by 2-inch specially-treated Krupp non-cemented steel made at the company's armor-plate works at Sheffield. The armament consists of ten 12-pounder quick-firing guns mounted as follows: three on forecastle deck, three aft on upper deck, four on upper deck in waist of ship; also eight 3-pounder quick-firing guns and two 18-inch torpedo tubes above water. When in commission the vessel will have a complement of about 290 men. The *Patrol*, the second vessel of this type now building by the firm, is also in an advanced state of construction.

Kennet, Jed.—The destroyers *Kennet* and *Jed* of 550 tons, built by Thornycroft, have not yet passed successful trials for their 25-knots contract speed. This failure is attributed to the form of hull, changed from the original design at the request of the builders.

These vessels are to be docked, when changes will probably be made in the form of stern when it is thought that the desired speed will be reached.

Submarine A 1.—The results of the inspection of the refloated British submarine *A 1*, which was sunk by collision with the liner *Berwick Castle* off the Isle of Wight, has enabled a tangible hypothesis to be obtained concerning how the crew met their death. Examination of the submarine in drydock showed that the liner struck the submerged craft on the conning tower about 15 feet below the surface. The optical tube was bent to port, a ventilator broken and the conning tower dented. The actual rent in the hull of the vessel, however, was very small. It appears that the crew within the submarine were all stunned by the force of impact arising from the collision, and were drowned without recovering consciousness. This theory is substantiated by the fact that the leak could have easily been stopped from within and the submarine brought to the surface by blowing the ballast tanks, whereas none of the latter were blown. Every member of the crew was found at his appointed position. All the plates around

the conning tower were found to be intact, and the vessel is but slightly damaged. The craft will be overhauled and will soon be ready for service once more.

FRANCE.

Program for 1905.—In the course of 1905 thirty-three new ships will be laid down for the French Navy. Of these, one armored cruiser, four torpedo-boat destroyers and eight submarines will be commenced in Government yards, and twenty torpedo boats will be laid down in private yards. The whole number of new ships to be commenced, to be continued or to be completed in 1905 is accordingly one hundred and fifty-one, viz: six battleships, six armored cruisers, twelve torpedo-boat destroyers, ninety-six torpedo boats and thirty-one submarine boats. The armored cruiser which is to be commenced in 1905 is officially known at present as *C 17*, and is of the same type as the *C 16*, laid down in 1904.

The general characteristics of the *C 17* will be similar to those of the modified *Ernest Renan* type; but the plans are still under consideration and some changes of detail may be made in them. The four torpedo-boat destroyers proposed to be commenced in 1905 are to be of the *Stylet* type, which was commenced in 1903. They are officially known at present as *M 40*, *M 41*, *M 42* and *M 43*. They are to be 193 feet in length, and their maximum speed is to be 28 knots; they will be fitted with engines working up to 6,800 horsepower, and they will carry sufficient coal to enable them to steam 2,300 miles at 10 knots, or 217 miles at their maximum speed. They will each carry seven guns and two torpedo tubes.

The plans of the twenty torpedo boats proposed to be built in 1905 are still under consideration. The armored cruiser *C 17* will be laid down at Lorient, and the four torpedo-boat destroyers at Rochefort. Three of the submarines will be built at Cherbourg, three at Toulon and two at Rochefort; these plans are still under consideration. It may be interesting to note that six submarine boats were laid down in October, 1903, viz: three at Cherbourg and three at Toulon. They are to be named

Emeraude, *Opale*, *Rubis*, *Saphir*, *Topaze* and *Turquoise*. They will have a displacement of 422 tons each, and they will be 149 feet long by 13 feet beam. They will each be fitted with an engine propelled by accumulators, and working up to 600 horse-power. They are to be fitted with twin screws, and their speed is to be 12 knots; they will each carry a torpedo tube. It is proposed to lay down the submarines, or submersible boats, before the close of this year; four of them will be built at Cherbourg and twelve at Toulon. With regard to the ninety-five ships at present in course of construction, the *République* will be ready for her equipment in June, 1905, except her turrets, the *Démocratie* has just been launched. The *Patrie* was launched in December, 1903; the *Liberté*, *Justice* and *Verité* are still on the stocks. In view of the discussions in England over the merits or otherwise of the Belleville boiler, it is interesting to note that in French naval circles warm approval is expressed at the action of the Minister of Marine in deciding on that type of boiler for the new battleships *Démocratie* and *Verité*. The armored cruisers now in hand are the *Jules Michelet*, the *Victor Hugo*, the *Ernest Renan* and the *C 16*. The eight torpedo-boat destroyers on hand are the *Stylet*, *Tromblon*, *Pierrier*, *Obusier*, *Mortier*, *M 38*, *M 39* and *Claymore*. Of the twenty-three submarine boats at present in course of construction, sixteen are officially known at present as *Q 47* to *Q 62*.

Condé.—STEAM TRIALS.—Some new regulations for the steam trials of new ships have been issued, and are as follows:

1. Coal-consumption trial with fires lighted under half the boilers to last six hours.

2. Two trials, one at full speed for ten hours, and a second for three hours at the highest speed obtainable with three-fourths of the boilers in use.

3. A run of twenty-four hours at economical cruising speed.

Unless under special circumstances, which are to be reported to the Minister of Marine at the time, the time between the two trials is not to exceed three days. The order in which the trials are to be taken is to be a matter of arrangement between the Trials Committee and the contractors.

The first-class armored cruiser *Condé* has successfully completed her trials, and is the first ship to have practically run them under the new conditions. Her trials really commenced March 23d, but they had to be given up owing to the leaky condition of her condensers; the necessary repairs occupied some six weeks, but when completed, the trials were carried through in seven days. The *Condé* is a ship of 10,014 tons displacement, with engines, according to the contract, developing 20,500 I.H.P., to give a speed of 21 knots. At the full-speed trial the engines developed a mean of 22,175 I.H.P., and a maximum of 22,800, an excess over the contract of over 2,000 H.P., the speed being 21.4 knots, with a coal consumption of 148 kg. (326.19 pounds) per square meter of grate surface (30.34 pounds per square foot). At the twenty-four hours' run at 10,000 H.P., the engines actually developed 9,900 I.H.P. giving a speed of 18.6 knots, with a coal consumption of 734 gr. (1.62 pounds) per H.P. per hour.

Like her counterparts, this cruiser seems to have undergone considerable strains during her full-power trials, particularly in the hull construction at the stern, and the after part will be reenforced before she goes into service.

While the old method often required several weeks or even months for the completion of the trials, it is questioned whether the new order does not introduce certain disadvantages by which necessary and advisable repairs are prevented when defects are discovered, thus leaving the success of the trial dependent upon good luck rather than good judgment.

Sabre, Balliste.—The destroyer *Sabre* has successfully completed her trials at Rochefort; with the engines developing 6,500 I.H.P., the mean speed during her full-speed trial was 29.725 knots, more than a knot and a half over the contract, the coal consumption being 689 gr. (1.52 pounds) per H.P. per hour. A sister vessel, the *Balliste*, has also concluded her trials. At her coal-consumption trial, with the engines making 219 revolutions and developing 4,000 H.P., a speed of 18.79 was maintained with a coal consumption of 877 gr. (1.93 pounds) per H.P. per hour.

Torpedo Boat No. 293.—STEAM TRIALS.—The first vessel of the French Navy to be fitted with Parsons' steam turbines has

just concluded her official trials at Cherbourg. She is numbered *293* and is a first-class torpedo boat, of the following chief dimensions: Length, 39.5 meters (130 feet); breadth, 4.25 meters (14 feet); displacement, including 19.48 tons load, 94.625 tons. She has been built as far as possible of the same type as the other boats of her class, modified only to suit a hull propelled by turbine engines; the armament (consisting of a bow and a deck torpedo tube and two 37-millimeter guns), as well as the interior and deck arrangements, are all identical with those of the latest reciprocating-engine boats.

Steam is supplied by two Normand water-tube boilers of the ordinary type, working at 17.5 kilogrammes per square centimeter (250 pounds per square inch) pressure.

The hull and boilers were constructed by Normand & Co., at Havre, the turbine engines being built by the Parsons Company, at Wallsend-on-Tyne, whence they were shipped to Havre, and fitted on board before launching.

In general arrangement the turbine installation belongs to the same class as that of the *Turbinia* and *Tarantula;* that is to say, the expansion of steam is carried out in three principal turbines in series, as distinct from the other and more general three-shaft disposition, which is used for Channel steamers for instance, where there are two low-pressure turbines in parallel, each receiving half the exhaust steam from the high-pressure turbine. In *No. 293* the high-pressure turbine is fitted on the port wing shaft, and exhausts into the intermediate pressure, driving the starboard wing shaft. This, in turn, exhausts into the low-pressure turbine on the center shaft.

The above-described triple series is, however, only used when speeds exceeding 17 knots are demanded. For all lower speeds an additional high-pressure turbine (usually called a cruising turbine) is employed, and the ordinary high pressure, which receives its exhaust, becomes a first intermediate. This cruising turbine is placed on the center shaft and coupled to the low-pressure turbine. When not required, steam is simply shut off from it, and it is allowed to revolve idly in the vacuum caused by opening its drain-pipe to the condensers.

There are two condensers of the ordinary Normand type, Weir main and auxiliary feed pumps, air pumps driven by reduction worm gearing from center turbine shaft, Normand feed heater and filter, as well as the usual auxiliary outfit of the boats of this class. In spite of this there is very comfortable space in the engine room, and very easy access to all engines, main and auxiliary.

Reversing is effected by a special series of reversing blades fitted in the aft end of the low-pressure turbine, the exhaust being carried to the condensers through the usual pipes.

The three shafts are supported outboard, each at two different points by brackets, and one propeller only is fitted on each shaft, thus marking a progressive departure from the *Turbinia* with her nine screws and the *Tarantula* with six. In the case of *No. 293*, small as the propellers appear, the slip is only 22.2 per cent. at full speed, and the slip curve is then actually showing a tendency to fall. Of course, in order to attain such results as the above, very special care must be used in the proportioning of the elements of the screws.

After a series of preliminary runs at Havre, which demonstrated the capability of the boat to fulfil the contract conditions of 24 knots speed, she was presented at Cherbourg for official trials carried out by a commission of French naval officers and engineers. The series commenced with an eight-hours' consumption trial at 14 knots, which gave a result of 347 kilogrammes (765 pounds) per hour, with a rather foul bottom.

On the full-power trial, consisting of six runs on a measured distance, and two-hours' continuous full-speed run, the speeds reached were:

	Knots.
Mean of first three runs, - - - -	26.308
Speed on two-hours' continuous run, -	26.205
Mean of second three runs, - - -	26.663

Steam was maintained very easily with an air pressure not exceeding 100 millimeters (3.93 inches), the quantity of coal burnt being exactly 2 tons per hour.

Of course, the consumption of fuel or steam by turbine-en-

gined boats is not readily compared with that of boats of ordinary type, on account of the lack of a common horsepower basis. A very closely approximate calculation can, however, be made of the power required to drive the *No. 293*, owing to her similarity to existing first-class torpedo boats, and this calculation brings out the interesting fact that at 14 knots, when using only 18 per cent. of the full power, the consumption of fuel is exactly the same per unit of power developed as it is at full speed. Of course, the consumption of steam is lower per horsepower at full speed, but the extra consumption at 18 per cent. power is not greater than the difference in evaporative efficiency between a boiler working with 100 millimeters air pressure and one with natural draft. In other words, the higher boiler efficiency at low power has in this case exactly compensated the lower turbine efficiency. As at 14 knots the cruising turbine is not working with full admission, it is probable (though it cannot be stated with absolute certainty) that at 17 knots, when the cruising turbine is taking a full steam admission, while the air pressure in the stokehold is still moderate, the fuel economy per unit of power would be more favorable than at any other speed. As speeds round about 17 knots are very largely used by torpedo-boats in maneuvering, the value of the cruising turbine system is apparent.

The general performance of the *No. 293* must be admitted to be good—26½ knots is a high speed for a 130-foot boat, and it is doubtful whether any other country except France possesses boats of this length that can do it, especially when the heavy load carried is taken into consideration, though there are numerous flotillas in other navies which, with the same load and speed, require to be over 150 feet long, with displacement exceeding 140 tons.

After exhaustive trials the engines of *No. 293* were opened, and found in perfect order. On trial, after closing up again, some experiments on reversing power were made, when it was found that the boat could be stopped dead from a speed of 20 knots in four-and-a-half times her own length.

There are two other systems of turbines for torpedo boats

under trial in France, but the *No. 243*, which has been for some years in hand, is not yet perfected, and the other—*No. 294*—has not yet been launched. It will be interesting to compare the results afforded by these systems—the Rateau and the Breguet—with those described for the *No. 293*, with Parsons' turbines.

Torpedo Boat No. 281.—In her full-speed trials this torpedo boat fell slightly below her requirements for speed, making 25.85 knots instead of the 26 knots for which she was designed.

As the machinery worked well and the difference of speed is small she will be placed in service at once.

Torpedo Boat, First Class, No. 285.—This new torpedo boat was launched from the Graville Works, near Havre, May 28th. General characteristics: Length, 121.3 feet; beam, 13.78 feet; draught, aft, 8.59 feet; displacement, 94.4 tons; speed (designed), 26 knots; bunker capacity, 10½ tons; probable radius of action, 1,800 miles at 10 knots and 200 miles at 26 knots.

There will be a single vertical triple-expansion engine of 2,000 designed I.H.P. and two Normand boilers.

There will be two torpedo tubes and two 37-mm. rapid-fire guns.

GERMANY.

Lothringen.—LAUNCH OF.—The first-class battleship *Lothringen* (*ex-M.*) was launched from the Schichau Yard, Dantzig, on May 27th.

Her dimensions are as follows: Length, 398 feet between perpendiculars, 430 feet over all; beam, 73.82 feet; displacement, 13,400 tons, with a mean draught of 25.75 feet. The triple-expansion engines, to drive three screws, are to develop 16,000 I.H.P., to give a speed of about 19 knots. There are two sets of boilers, six cylindrical and eight water-tube of the Schultz type. The normal coal supply will be 1,000 tons, but 1,500 can be carried on an emergency, with 200 tons of oil.

Protection is afforded by a complete armor belt of Krupp steel, 9 inches thick, tapering to 4 inches at the extremities; above this is another belt 240 feet long of 6-inch steel, and a central battery 180 feet long above this again, also protected by 6-inch armor.

The armored deck is 1.5 inches thick on the flat and 3 inches on the slopes; the transverse bulkheads are 6 inches thick. The barbettes for the heavy guns, with their hoods, are 11 inches thick; the small turrets, 7 inches; while the fore conning tower is 12 inches and the after one 5.5 inches. The total weight of armor is 4,200 tons.

The armament will consist of four 40 caliber 11-inch guns, in pairs in the barbettes, one forward and one aft; fourteen 40-caliber 6.7-inch Q.F. guns, four in turrets on the upper deck and ten in the casemated battery on the main deck, with twelve 3.4-inch and twelve 1-pounder Q.F. guns, and six 17.7-inch torpedo tubes, one submerged in the stem, two submerged on each broadside and one above water in the stern.

York.—LAUNCH OF.—The first-class armored cruiser *York* (*Ersatz Deutschland*) was launched on June 14th from the yard of Blohm & Voss, at Hamburg, the keel plate having been laid April 25, 1903. She is somewhat similar to the *Prinz Heinrich* class, but is of an improved type. The hull is of steel, without sheathing. She will have two military masts, each carrying one top, and two funnels. The bow is high, and the superstructure extends from the stem to a point just forward of the after turret. The complement will be 528, or, as a flagship, 571.

Her principal dimensions are: Length, 413 feet 6 inches; beam, 65 feet 7 inches; mean draught, 24.3 feet; displacement, about 9,550 tons. She will have three 4-cylinder triple-expansion engines, designed to develop 19,000 I.H.P., and give a speed of 21 knots, steam being supplied by sixteen Dürr water-tube boilers. The coal supply, at load draught, will be 1,000 tons, with a total capacity of 1,500 tons.

Protection is afforded by a complete belt of Krupp steel, 7.5 feet wide, 3.9 inches thick amidships, and 3.2 inches at the ends. Above this, and extending up to the gun deck for a length of 165 feet amidships, the side is covered with 6-inch armor; and above this again is the casemate for the 5.9-inch guns, protected by 4-inch armor. The protective deck, behind the belt and sloping down at the sides to meet the lower edge of the latter, is 2.8 inches thick on the slopes and 1.6 inches on the flat. The flat armor

deck over the upper side armor, outside the casemate, is 1.2 inches thick; and the deck over the casemates is 1.4 inches. The turrets for the 8.27-inch guns are 5.9 inches thick, and rest on barbette towers of the same thickness. The armor of the 5.9-inch turrets is 3.9 inches thick in front and 3.2 inches in rear, and of the 5.9-inch casemates, 3.9 inches. The forward conning tower is 16 inches thick, and the after one 3.2 inches, of special steel. The ammunition tubes for the 8.27-inch guns are 3.9 to 3.2 inches thick; for the 5.9-inch turrets, 3.2 inches.

Her armament will consist of four 8.27-inch Krupp guns in pairs in turrets forward and aft, the forward turret being on the superstructure (or upper) deck, and the after one on the main deck. These turrets are to be worked by hydraulic power. Ten 5.9-inch guns—three each side in a long casemate on the gun deck, forward pair firing directly ahead, and after pair directly astern; and four in four turrets, two each side, over the casemates for the other 5.9 inch guns. The upper works are thrown inboard to permit bow and stern fire from these turrets. There are twelve 3.47-inch guns in the superstructure and on the upper deck and bridges, and ten machine guns, with five submerged torpedo tubes, one in the stem, and one on each beam, and one above-water torpedo tube in the stern on the berth deck, protected by armor.

The ship is to be completed ready for turning over to the authorities by the beginning of 1906.

Lubeck, München.—LAUNCH OF.—Two third-class cruisers of the improved *Arcona* class have recently been launched, the *Lubeck*, on March 26th, from the Vulcan Yard at Stettin, and the *München*, on June 30th, from the Weser Yard, Bremen. The dimensions of these vessels are as follows: Length, 361 feet; beam, 40 feet 4 inches, with a draught of 16 feet 5 inches on a displacement of 3,200 tons. The two triple-expansion engines are to develop 10,000 I.H.P., giving a speed of 22 knots, steam being provided by ten Schultz water-tube boilers. The coal stowage will be 800 tons, giving a radius of action of 5,000 miles at 10 knots. There is an armored deck 1 inch thick on the flat and 2 inches on the slopes, with a 3-inch conning tower. The

armament will consist of ten 4.1-inch and twelve 1.4-inch Q.F. guns, with two submerged torpedo tubes for 18-inch torpedoes.

Hamburg.—TRIALS OF.—The trials of the *Hamburg*, (mentioned on pages 357 and 360 of the February JOURNAL), the first of the improved *Arcona* class to be completed, have been completed successfully. The ship was built by the Vulcan Yard, Stettin, and has been finished within 16 months of her laying down. At her twenty-four hours' coal-consumption trial at 7,000 I.H.P., the engines actually developed 7,244 I.H.P., making 124 revolutions, with a coal consumption of 0.827 kilogram (1.82 pounds) per I.H.P. per hour, the air pressure being 19 mm. (.74 inch). At the six hours' full-speed trials under forced draft the engines developed 10,746 I.H.P. (746 in excess of the contract), with an air pressure of 40 mm. (1.57 inches), the mean revolutions being 141, and the mean speed 22 knots. During four runs on the measured mile a speed of 22.5 knots was attained, the engines developing 11,889 I.H.P. (1,889 over the contract), and making 145.4 revolutions. During a further run at full speed in deep water, a speed of 23.1 knots was attained, the engines developing 11,582 I.H.P., with an air pressure of 43 mm. (1.69 inches), and making 147 revolutions. The ship has ten small-tubed water-tube boilers of the Schultz type, and both engines and boilers worked without a hitch.—" J. R. U. S. I."

Oil Fuel.—The use of oil fuel is being extended in the Navy. Several of the torpedo boats in addition to some of the larger ships are now fitted to consume oil. The Imperial yacht *Hohenzollern* is so fitted, while all the new battle ships of the *Braunschweig* type carry 200 tons of oil in their double bottoms. Large tanks have been erected in the dock yards at Kiel and Wilhelmshaven, and at the coaling stations at Holtenau and Brünsbuttel for the storage of oil, while an oil transport ship has recently been delivered at the Imperial dockyard at Kiel specially built and fitted for replenishing the oil supplies in ships at sea or in harbor. The vessel is divided into twelve large watertight compartments, besides being built with a double bottom; six of these compartments are used for the storage of oil, while in the after part of the ship is a powerful pumping equip-

ment for supplying the oil to other ships, and a steam heating apparatus for maintaining it at a proper temperature. Another similar vessel is to be constructed, and it is believed that much time and trouble will be saved to the ships of the squadrons to which these transports are attached, as it is much easier for ships to replenish their supply of oil from them than it is to coal at sea, which latter operation can only be carried out under favorable conditions of wind and weather.

ITALY.

Italian Navy.—The Italian naval estimates for 1904–5 foot up to $25,438,215, or $1,875 more than the corresponding estimates for 1903–4. The amount proposed to be devoted to new construction in 1904-5 is $7,667,345. It is intended to proceed with the completion of the cruiser *Francesco Ferruccio*, and to continue the building of the battleships *Vitorio Emanuele*, *Napoli*, *Regina*, *Elena* and *Roma*. It is further proposed to lay down a battleship or a cruiser at Castellamare; to build three submarines of the *Glauco* type; to complete the torpedo-boat destroyers *Zeffiro* and *Espero;* and to construct fourteen first-class torpedo-boats.

Zeffiro.—During the machinery trials of the torpedo destroyer *Zeffiro*, 330 tons, an accident occurred by the bursting of a steam pipe, causing much damage in the engine room and seriously injuring everybody in the engine room at the time.

MERCHANT SHIPS.

Minnesota.—This vessel is the sister ship of the *Dakota*, described on page 707 of the May JOURNAL, and has just completed her fitting out for her intended service in the Pacific for the Great Northern Steamship Company.

Her principal characteristics are recapitulated: Length, over all, 630 feet; length, between perpendiculars, 622 feet; beam, extreme, 73 feet 6 inches; gross tonnage, 20,718 tons; net tonnage, 13,323 tons; displacement at full load (about) 33,000 tons. The propelling machinery placed in two watertight compartments, consists of twin triple-expansion engines to develop about 10,000 I.H.P., and to give a speed of about 18 knots. Diameters of cylinders 29 inches, 51 inches and 89 inches; stroke, 57 inches. Water-tube boilers of the Niclausse type are installed in two watertight compartments, to furnish steam at 250 pounds pressure.

The sister ship to the *Minnesota*, the *Dakota*, is now being completed at the shipyard in Groton, Connecticut, opposite New London, and will soon follow the *Minnesota* around to the Pacific. These ships were built by the Eastern Shipbuilding Company, of New London, Connecticut, which was organized especially for the purpose of building the vessels. The shipyard was laid out, the buildings erected, and machinery installed at the same time as the work on the hulls progressed.

New Cunard Liner Caronia.—The Cunard liner *Caronia*, launched July 13, from the Clydebank Works of John Brown & Co., is the largest ship yet floated on the Clyde, although the firm have on hand one of greater dimensions, 760 feet, as compared with 678 feet, and to attain a continuous speed at sea of 25 knots.

Built to the highest class of Lloyd's special survey, and to meet British Admiralty requirements as a transport and armed cruiser, she represents the accumulated experience of the Clyde-

bank Works, so far as structural details and building methods are concerned.

Considerable expedition has been displayed in carrying out the work of constructing the hull. The keel plate was laid on September 21, 1903, so that the time that has elapsed in preparing this vessel for launching is only nine and a half months. The steel work is finished, with the exception of the erections in the way of the machinery openings. The carpentry and joinery work is two-thirds completed, and all other work, including the construction of the boilers and machinery, is in the same advanced state. The best measure of progress is found in the fact that the launching weight of the ship was 13,500 tons, which is greater than that of any ship which has been put into the water on launching ways.

The principal dimensions of the *Caronia*, and of a sister ship, the *Carmania*, being built at Clydebank, and to be fitted with steam turbine machinery, now being constructed at the same works, are: Length over all, 678 feet; breadth (molded), 72 feet; depth to sheltered deck, 52 feet; gross tonnage 21,000 tons; draught of water when loaded, 32 feet; displacement at this draught, 29,800 tons; dead-weight cargo capacity at this displacement, 12,000 tons; continuous speed at sea, 18 knots.

The navigating and deck machinery is of a powerful character. There are two steering engines of very heavy proportions—one under the water line, so that there is little chance of this important item for the navigation of the ship being affected by gunshot when the vessel is used as an armed cruiser; the other steering engine is placed on a higher level. The rudder stock, 19½ inches in diameter, is extended to the upper deck, and can be operated by either of the two steering engines. The capstan and windlass gears for working the heavy anchors are of the Napier Brothers manufacture, and are probably the heaviest which have been fitted to any merchant ship. The navigating bridge is placed in a high position, so as to command a wide circle, and the captain has, within arm's reach, apparatus whereby he can control every movement, both at sea and while entering docks.

The upper decks of the *Caronia* are given over to the carriage of passengers, and the wide experience, not only of the builders, but also of the owners, has resulted in an admirable system of cabin distribution and arrangement, so as to afford absolute comfort on the voyage. The vessel has accommodation for the following numbers of passengers of the respective classes: First-class, 300; second-class, 350; third-class, 1,000; steerage, 1,000; total, 2,650. When to these be added the 450 officers and men constituting the crew, the total population of the ship will be 3,100.

The main propelling machinery consists of two sets of quadruple-expansion engines to develop about 21,000 I.H.P. The cylinders are 39 inches, 54½ inches, 77 inches, and 110 inches in diameter respectively, with a stroke of 66 inches, and they are arranged to reduce vibration to a minimum. Each cylinder is fitted with a separate liner of hard cast iron. The high-pressure and the first intermediate-pressure cylinders are each fitted with a piston-valve, each second intermediate-pressure cylinder with one treble-ported flat slide-valve, and the low-pressure cylinder with two treble-ported flat slide valves. Assistant cylinders are provided for all the flat slide-valves. The valve-gear is of the double-eccentric link-motion type. The reversing of the engines is effected by means of direct-acting steam and hydraulic engines.

The shafting is of steel throughout, manufactured at the Sheffield works of the builders. Each crank-shaft is in four pieces, and is of the built type. The crank-shafts are 22¼ inches in diameter, the tunnel-shafts 21¼ inches, and the propeller shaft 23½ inches. The thrust-blocks are of the ordinary horseshoe pattern, both ahead and astern surfaces being lined with white metal. The propellers are four-bladed, the bosses being of cast steel and the blades of manganese bronze.

The main condensers are cylindrical in form and built of steel plates, the ends and doors being of brass. Circulating water is supplied by two centrifugal pumps, one to each condenser, and each pump is driven by two engines. There are two sets of feed pumps, each set consisting of four Weir pumps, capable of deal-

ing with the feed water necessary for the full power. Two direct-contact heaters are fitted in connection with the feed pumps. The remainder of the auxiliary machinery includes two feed-water filters, separate evaporating plants for both feed make-up and drinking-water purposes, and a complete installation of pumps for bilge, ballast, fire, and sanitary purposes. A separate condensing plant is also provided for the auxiliary machinery.

The boiler installation consists of eight double-ended and five single-ended boilers, designed for a working pressure of 210 pounds per square inch. They are arranged in two separate boiler rooms, with two elliptical funnels, which rise to a height of 135 feet above the level of the furnace bars. The boilers are to work on Howden's system of forced draft, and two large fans, each driven by two engines, are supplied for each boiler room to provide the air necessary for combustion.

Antrim.—The first of the vessels for the Midland Railway Company has completed her specified trials, and the results attained indicate a high propulsive efficiency, which does the highest credit to the builders, John Brown and Co., Clydebank. Their vessel, the *Antrim*, attained 21 knots on the measured mile and 20.6 knots on a six hours' run, and, in view of the conditions, this result establishes a high standard for comparison with the sister ship *Londonderry*, having turbine machinery. [A description of the *Antrim* appeared in the May JOURNAL, pages 627-634 and 713]. The trial was of six hours' duration, and commenced at noon on the 19th inst., by which time the guaranteed speed of 20 knots was reached. Four runs over the Skelmorlie measured mile were made between 12·15 P. M. and 1·30 P. M., giving a mean of means of exactly 21 knots. The vessel, after maneuvering for a time in the Firth of Clyde, was taken round Ailsa Craig, the trial finished at 6 P. M., opposite the Cloch. Over the whole period the average speed was 20.6 knots. It should be noted that the vessel has two double-ended and one single-ended boiler; but, in accordance with the contract provisions, the latter was not in use throughout the trials.

Manxman, Turbine-Driven Steamer.—Vickers, Sons, and Maxim, launched at Barrow-in-Furness, June 15, the turbine-

driven steamer *Manxman*, which they have built for the Midland Railway Company. The speed guaranteed by the builders is 20 knots, but it is not improbable that a rate of 22 knots will be realized. We have already referred to the salient features of the three other vessels already launched on the Clyde—the *Antrim*, *Donegal* and *Londonderry*, [May JOURNAL, pages 627-634, 713.] The last of these three, like the *Manxman*, is fitted with Parsons' turbines; but there is this most important difference in the Vickers ship—that the steam pressure is 200 pounds instead of 150 pounds, as in the case of all marine turbines so far fitted. As the two turbine-driven ships are almost identical, there will be an opportunity of ascertaining whether increased pressure improves the economy. Each turbine drives its own shaft, and each shaft is fitted with one three-bladed solid bronze propeller. The high-pressure turbine is placed in the center line of the ship, and the two low-pressure turbines at the sides. The turbines for driving the ship astern are incorporated with the low-pressure turbines, and the slide-valves for controlling the steam admission for ahead and astern working in these side turbines are independent of the high-pressure turbine, so that the latter in maneuvering will run idle. The reversing slide-valves are worked by large hand-wheels and worm-gearing, and all maneuvering gear is placed at the forward end of the engine room and arranged for easy manipulation.

The condensers are cylindrical in form, placed in the wings of the ship. They are supplied with circulating water from centrifugal pumps, with which are combined the air-pumps, fitted in duplicate for each condenser, and driven by independent steam-engines. The condensers are also fitted with Parsons vacuum intensifiers. Steam is supplied to the turbines by one single-ended and two double-ended boilers of the cylindrical type, working with forced draught on the closed stokehold system. The air pressure is provided by four steam-driven fans. There are two funnels. In the engine room there are fitted one pair of direct-acting feed pumping-engines for feeding the boilers, one duplex pump for sanitary purposes, two duplex pumps for bilge, fire, and wash-deck service, one feed-water heater, one feed-

water filter, and one small duplex pump for clearing the cattle scuppers, and also various pumps for oil and water circulation as required by the Parsons system.

In external appearance the *Manxman* is exactly the same as the three other vessels built for the Midland Railway Company, but internally there is considerable difference. She has been built for the Heysham and Isle of Man service, while the others have been constructed specially for the Belfast service and the accommodation of the Vickers vessel consists almost entirely of large saloons, instead of the small private cabins in the night steamers. But as the vessel may occasionally be required for the night service, one of the saloons on the upper deck has been arranged so that it may be converted on short notice into a number of small cabins. The dimensions of the vessel are: Length, 330 feet; beam, 43 feet; and depth, 26 feet.

BOOKS RECEIVED.

THE NAVAL POCKET BOOK.—Edited by SIR W. LAIRD CLOWES, and published by W. THACKER & Co., 2 Creed Lane, London.—This very convenient little book gives good information on nearly all naval subjects. The small price of 7s. 6d. is an additional reason for the popularity of the book among those who do not care to subscribe to more expensive annuals, but who also desire concise information.

The following is a summary of the contents:

The Navies of the World.—A complete list of every Battleship, Cruiser, Gunboat, Torpedo Boat and Destroyer, Harbor, Hospital, Training and Subsidiary Vessel, giving details of Displacement, Armament, Protection, Engines, Coal Capacity, etc.

A History of the Submarine, and particulars of the Submarine Fleets of the world.

Notes on Torpedoes, and full description of the various types used by British and Foreign Navies.

List of Dry Docks. Personnel of Leading Navies.

Plans of Ships, showing Armor, Decks, Guns, etc.

Tables for Conversion of Measures. Trial Trip Tables.

Steam Trials of British and Foreign Ships.

Complete Index of Ships by Name.

THE ROYAL NAVY LIST.—Messrs. Witherby & Co., 326 High Holborn, London, have issued the 106th number of "The Royal Navy List," which is published quarterly and is now in its 26th year.

This volume affords much valuable information concerning the Royal Navy, and is prepared in a form which permits more ready reference than the Admiralty publication, while many of the subjects treated, with their tabulated data, could only be obtained elsewhere by the most laborious research.

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